Meeting the Challenge of Distributed Real-Time & Embedded (DRE) Systems

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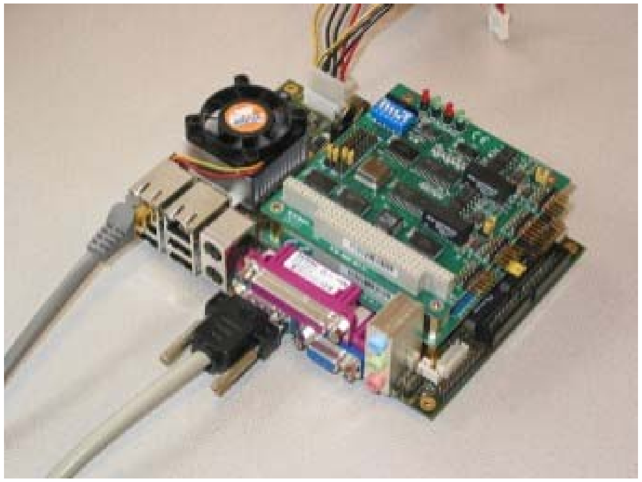
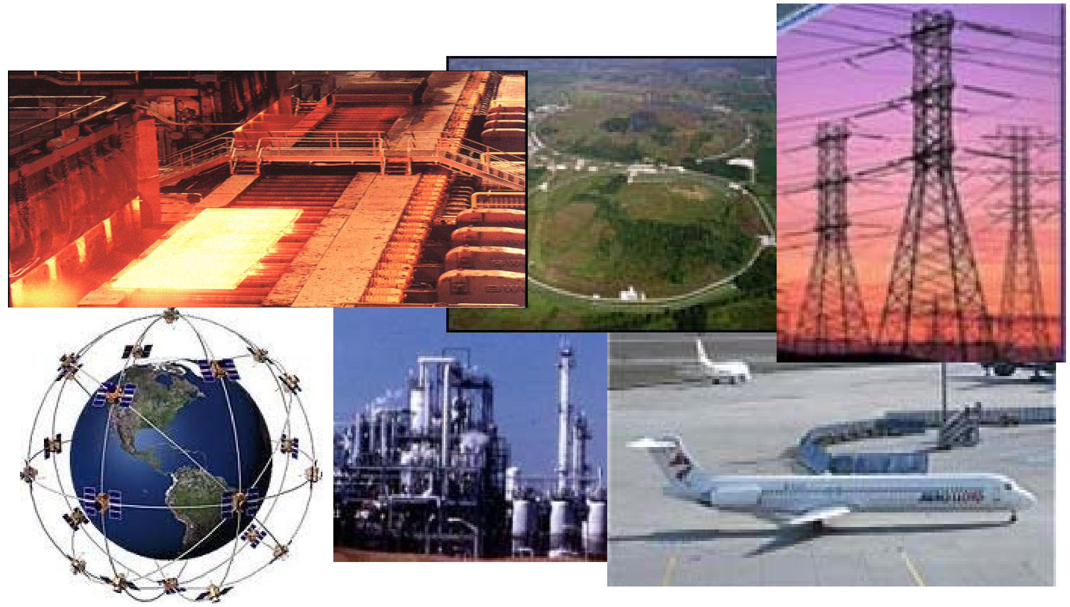
Evolution in DRE Systems

The Past



Standalone real-time & embedded systems
- Stringent quality of service (QoS) demands
  - e.g., latency, jitter, footprint
- Resource constrained

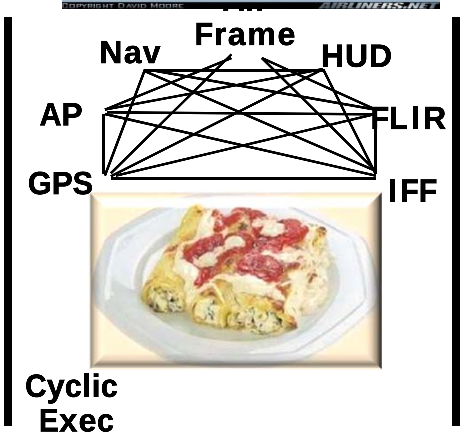
The Present

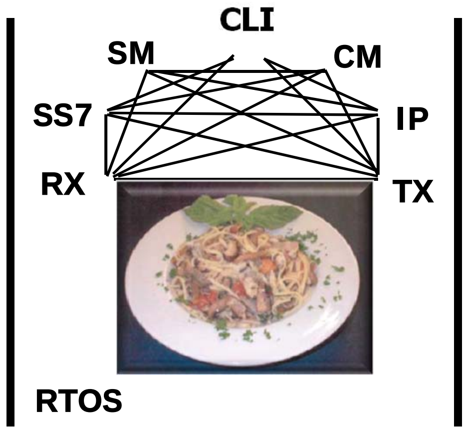


Distributed real-time & embedded (DRE) systems
- Net-centric systems-of-systems
- Stringent simultaneous QoS demands
  - e.g., dependability, security, scalability, etc.
- More fluid environments & requirements

This talk focuses on technologies & methods for enhancing DRE system QoS, producibility, & quality

Evolution of DRE Systems Development





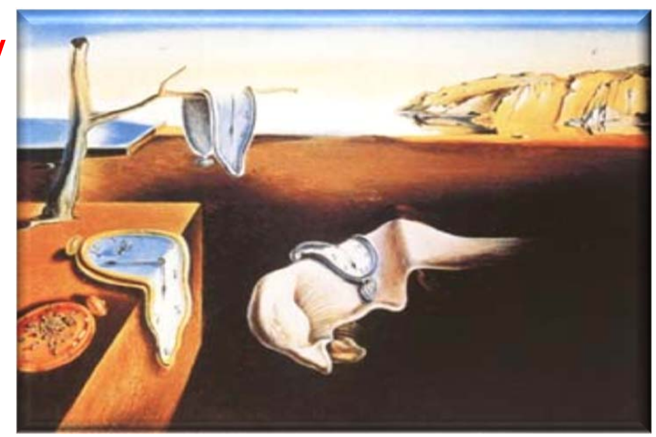
Technology Problems

- Legacy DRE systems are often:
  - Stovepiped
  - Proprietary
  - Brittle & non-adaptive
  - Expensive
  - Vulnerable

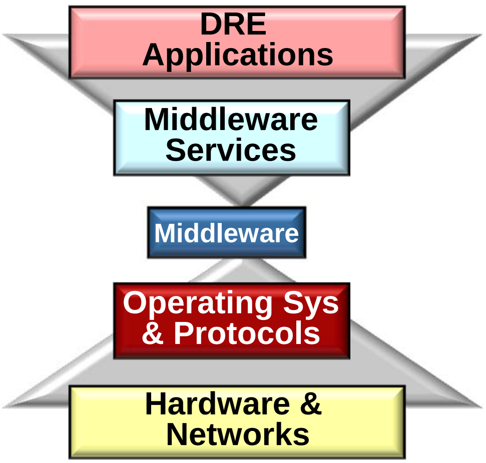
Mission-critical DRE systems have historically been built directly atop hardware, which is

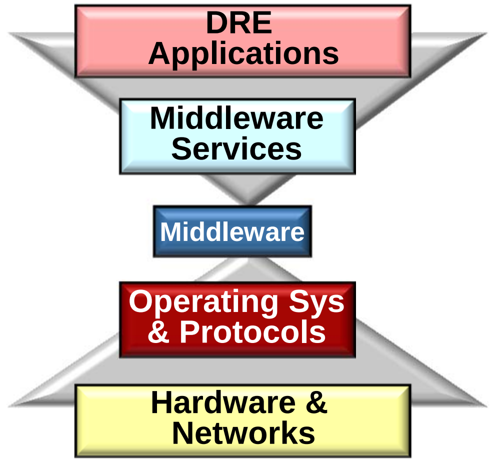
- Tedious
- Error-prone
- Costly over lifecycles

Consequence: Small changes to legacy software often have big (negative) impact on DRE system QoS & producibility



Evolution of DRE Systems Development





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Mission-critical DRE systems have historically been built directly atop hardware, which is

- Tedious
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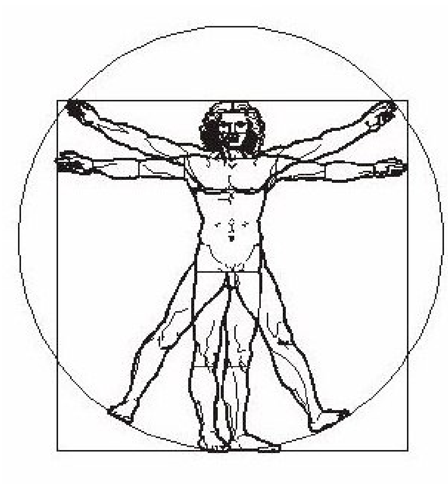
- Costly over lifecycles

What we need are the means to

- Enhance integrated DRE system capability at lower cost over the lifecycle & across the enterprise
- Reduce cycle time of developing & inserting new technologies into DRE systems

What's So Hard About DRE Software?

Human Nature



- Organizational impediments
- Economic impediments
- Administrative impediments
- Political impediments
- Psychological impediments

Technical Complexities

Accidental Complexities

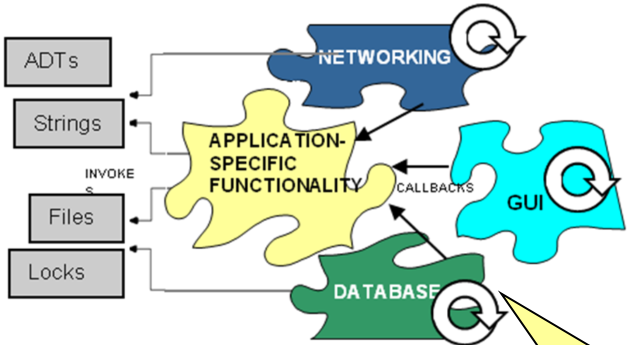
- Low-level APIs & debug tools
- Algorithmic decomposition

Inherent Complexities

- Quality attributes
- Causal ordering
- Scheduling & synchronization
- Deadlock avoidance
- ...

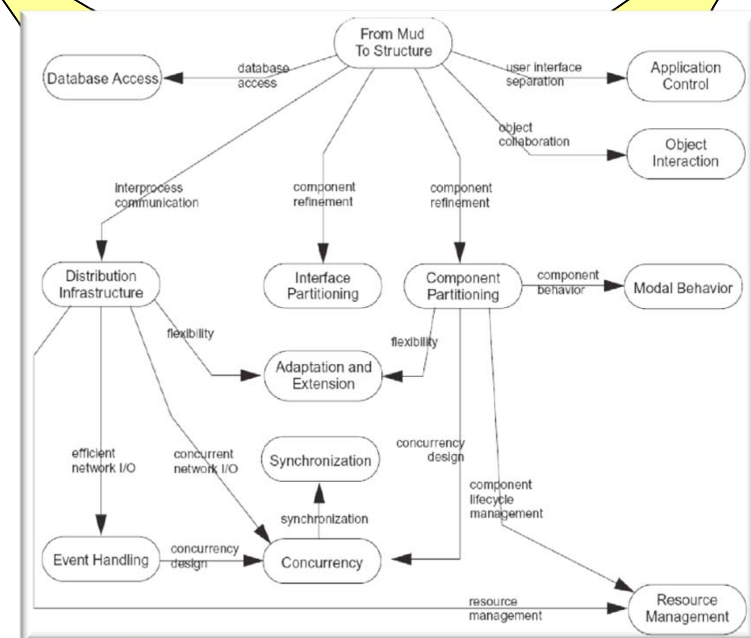
www.dre.vanderbilt.edu/~schmidt/reuse-lessons.html

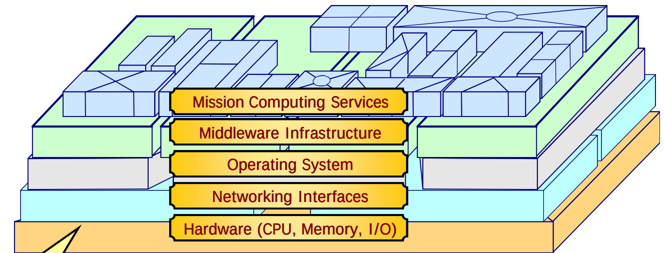
Systematic Reuse Capabilities for DRE Systems



Frameworks

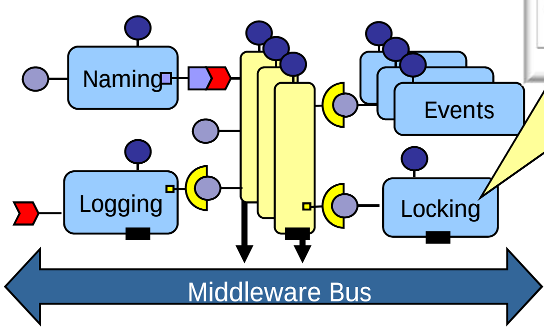
Patterns & Pattern Languages



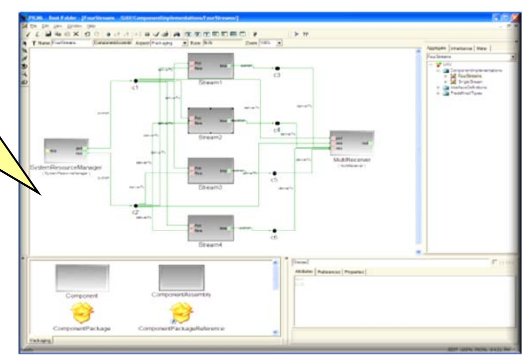


Software Product-lines

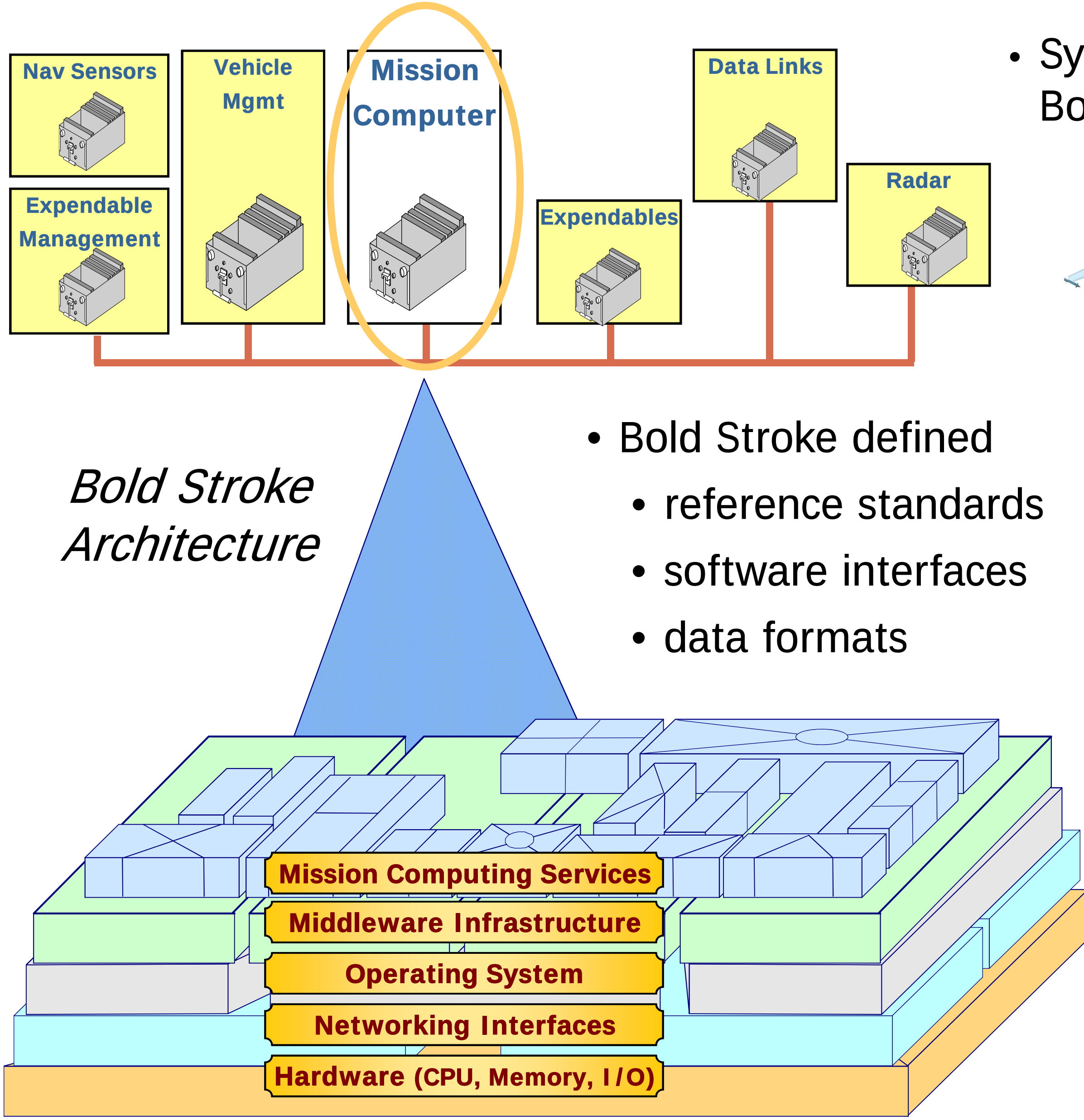
Component-based & Service-Oriented Middleware



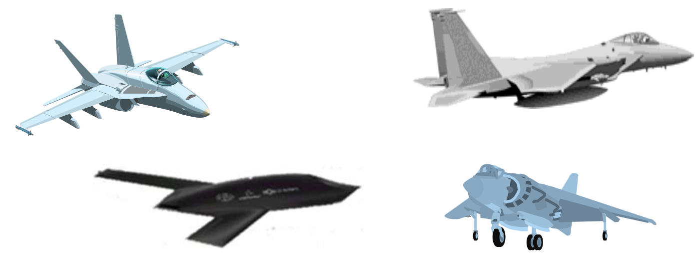
Model-Driven Engineering Tools



DRE System Case Study: Boeing Bold Stroke



- Systematic reuse platform for Boeing avionics mission computing

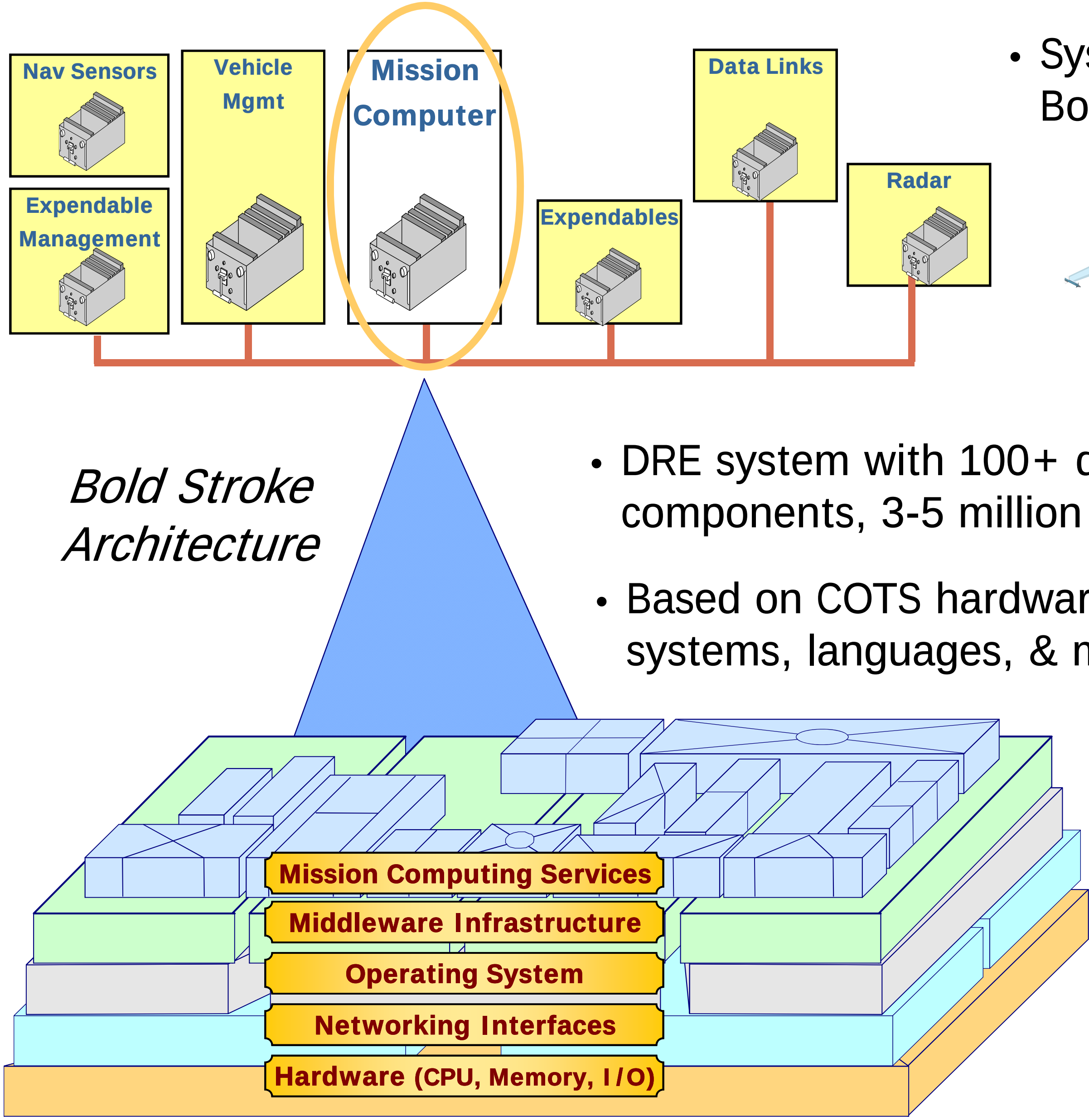


- Bold Stroke defined
  - reference standards
  - software interfaces
  - data formats
  - protocols
  - system services &
  - reusable components

  that enabled distributed computing & allowed distributed applications to coordinate, communicate, execute tasks, & respond to events in an integrated & dependable manner

splc.net/fame/boeing.html

DRE System Case Study: Boeing Bold Stroke



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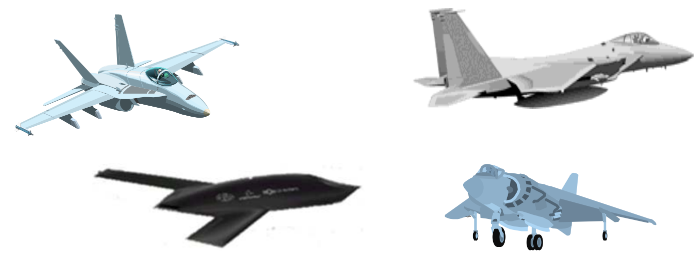
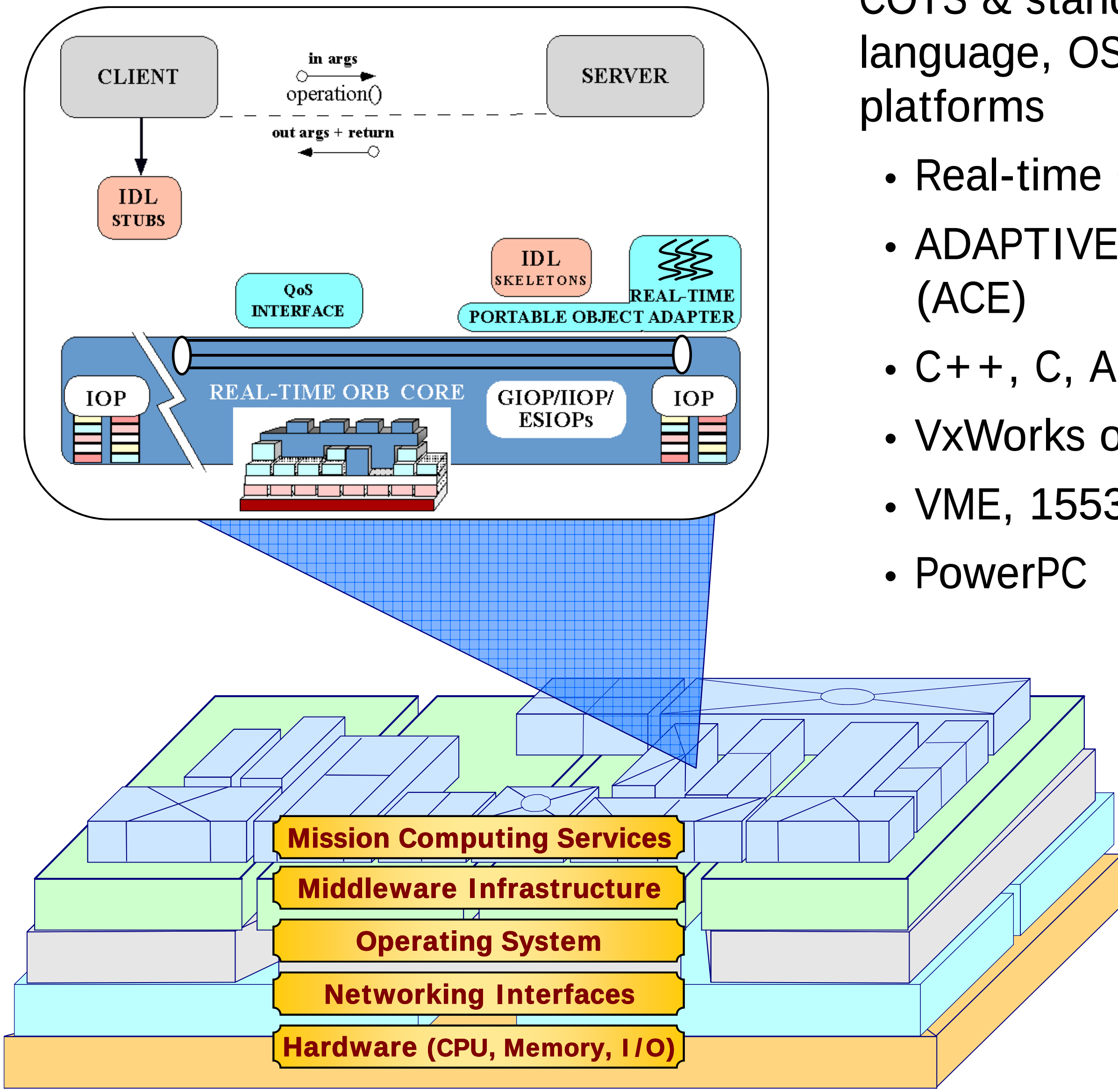


- DRE system with 100+ developers, 3,000+ software components, 3-5 million lines of C++/C/Ada/Java
- Based on COTS hardware, networks, operating systems, languages, & middleware
- Used as an Open Experimentation platform (OEP) for DARPA PCES, MoBIES, SEC, NEST, & MICA programs

splc.net/fame/boeing.html

Applying COTS to Bold Stroke



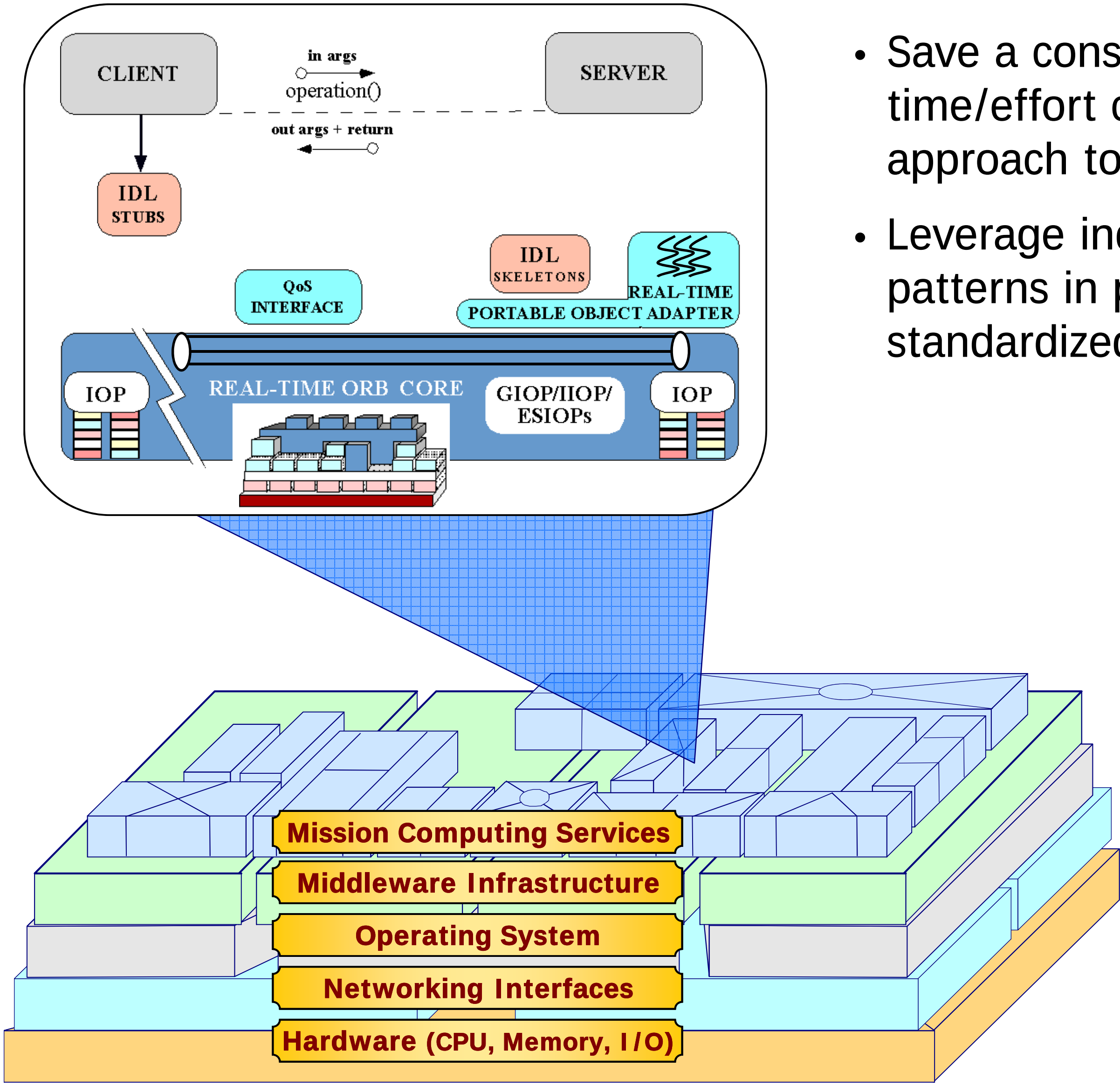
COTS & standards-based middleware, language, OS, network, & hardware platforms

- Real-time CORBA (TAO) middleware
- ADAPTIVE Communication Environment (ACE)
- C++, C, Ada, & Real-time Java
- VxWorks operating system
- VME, 1553, & Link16
- PowerPC

www.dre.vanderbilt.edu/ACE

www.dre.vanderbilt.edu/TAO

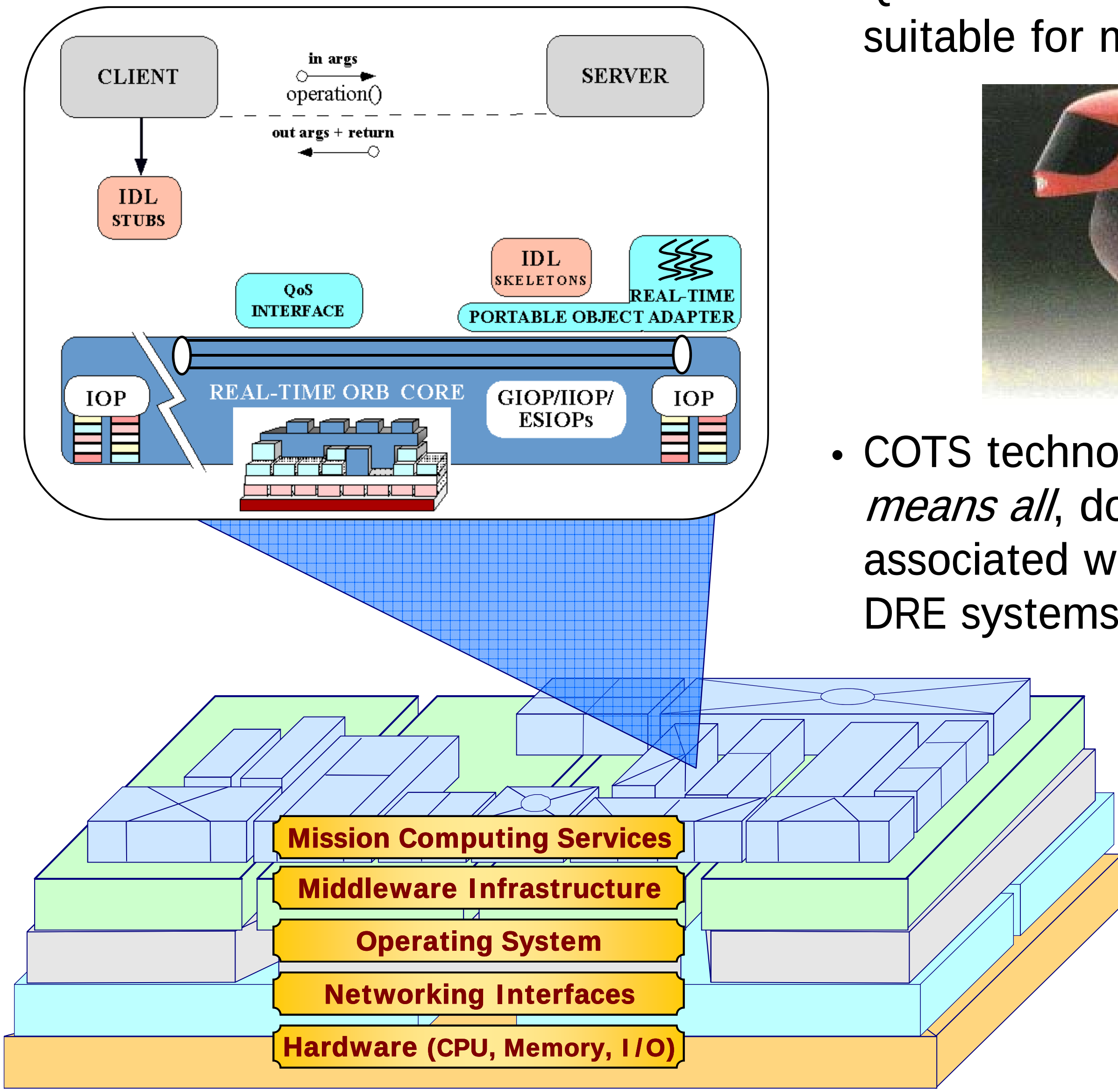
Benefits of Using COTS



- Save a considerable amount of time/effort compared with traditional approach to handcrafting capabilities
- Leverage industry “best practices” & patterns in pre-packaged (& ideally) standardized form

The use of COTS is essentially “outsourcing,” with many of the associated pros & cons

Limitations of Using COTS

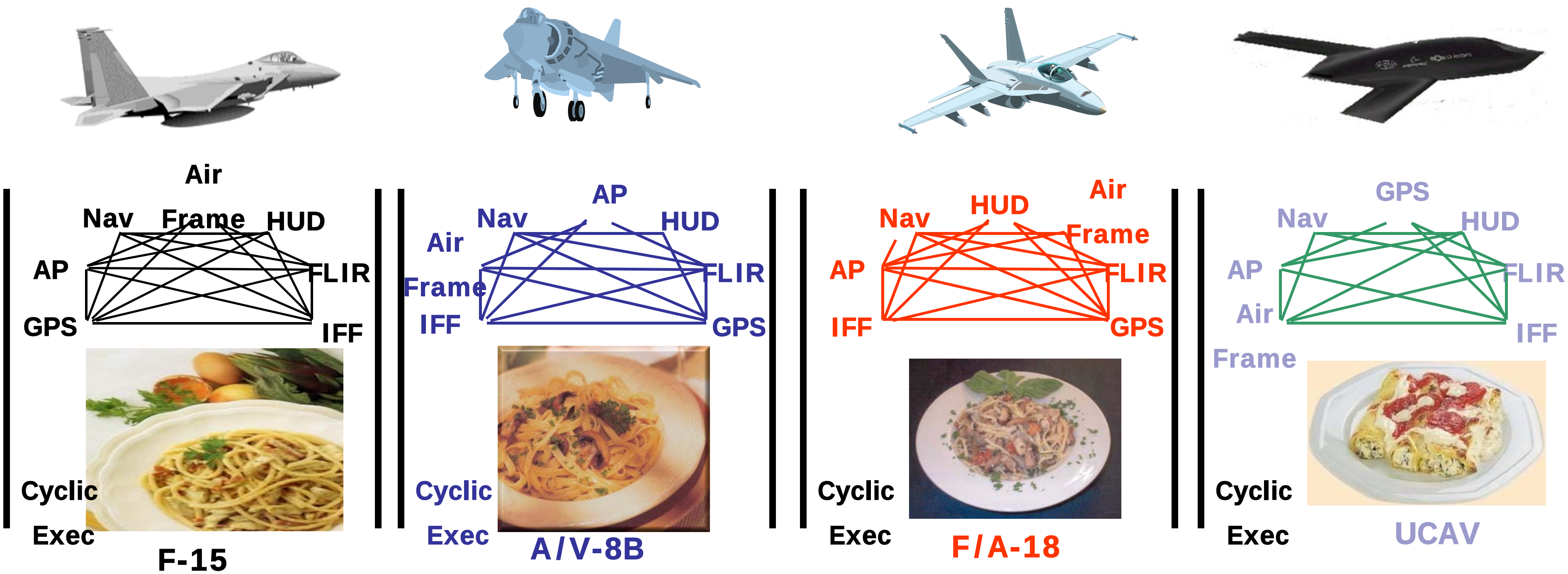


- QoS of COTS components is not always suitable for mission-critical DRE systems

- COTS technologies address some, *but by no means all*, domain-specific challenges associated with developing mission-critical DRE systems

What was needed was a systematic reuse technology for organizing & automating key roles & responsibilities in an application domain

Motivation for Software Product-lines (SPLs)

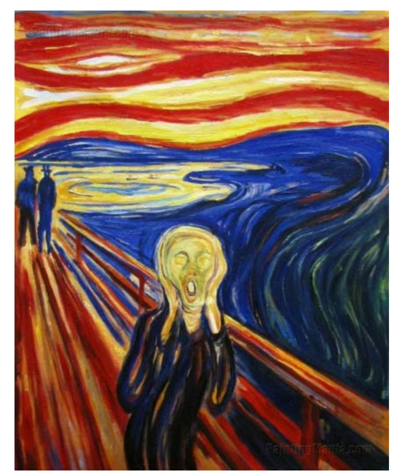


Legacy avionics mission computing systems are:

- Stovepiped
- Proprietary
- Brittle & non-adaptive
- Expensive
- Vulnerable

Consequences:

- Small changes to requirements & environments can break nearly anything
- Lack of any resource can break nearly everything



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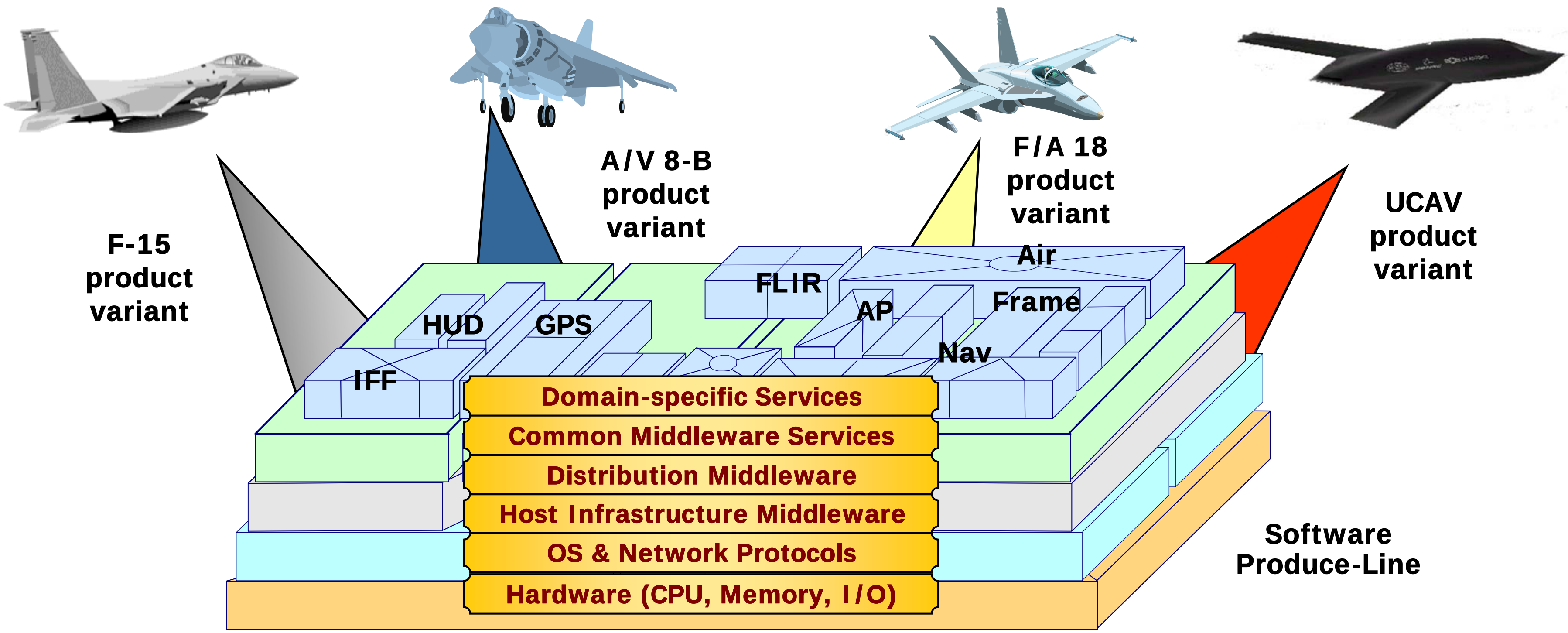
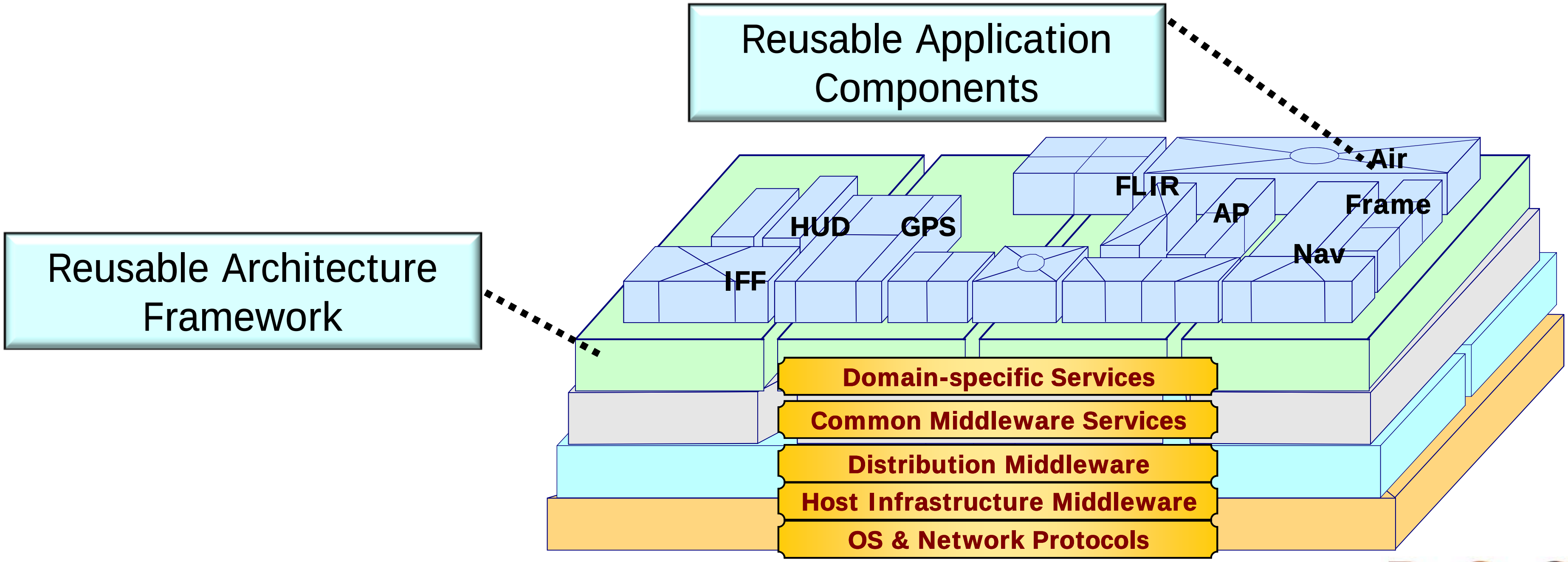


- SPLs factor out general-purpose & domain-specific services from traditional application responsibility in DRE systems
- Manage software variation while reusing large amounts of code that implement common features within a particular domain
- SPLs offer many opportunities to configure product variants
  - e.g., component distribution & deployment, user interfaces & operating systems, algorithms & data structures, etc.

Overview of Software Product-lines (SPLs)

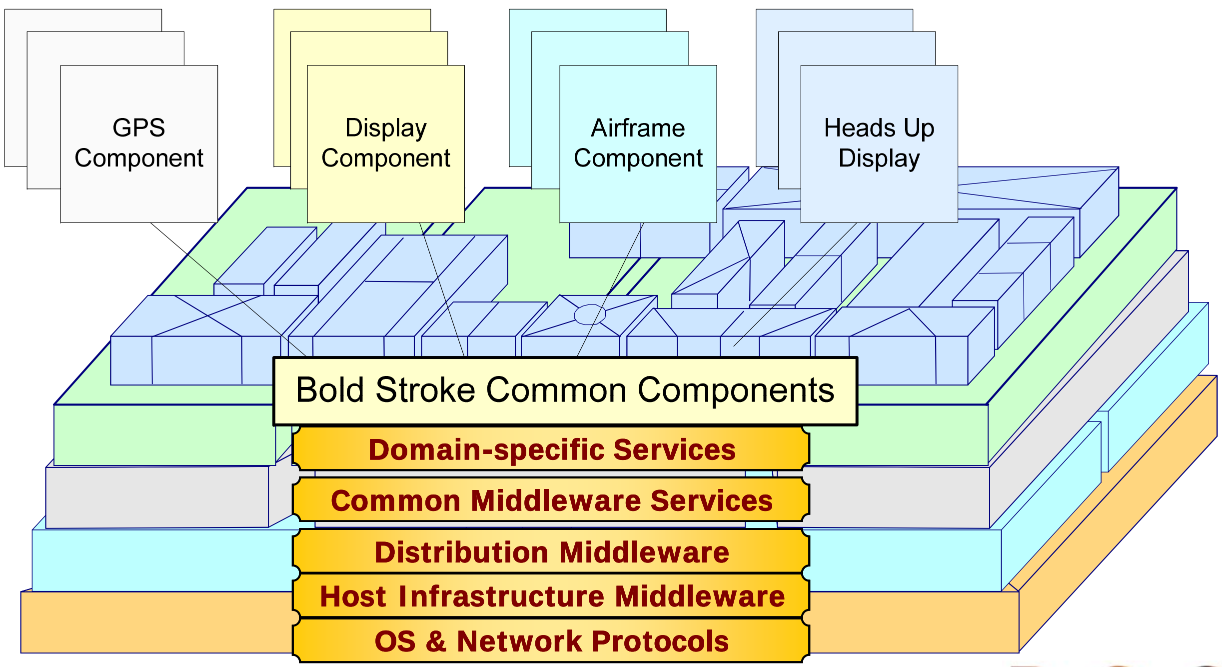
- SPL characteristics are captured via *Scope, Commonalities, & Variabilities (SCV) analysis*
  - This process can be applied to identify commonalities & variabilities in a domain to guide development of a SPL
- Applying SCV to Bold Stroke
  - Scope defines the domain & context of the SPL
    - e.g., Bold Stroke component architecture, object-oriented application frameworks, & associated components (GPS, Airframe, & Display)



Applying SCV to the Bold Stroke SPL

Commonalities describe the attributes that are common across all members of the SPL family

- Common object-oriented frameworks & set of component types
  - e.g., GPS, Airframe, Navigation, & Display components
- Common middleware infrastructure
- e.g., Real-time CORBA & Lightweight CORBA Component Model (CCM) variant called Prism

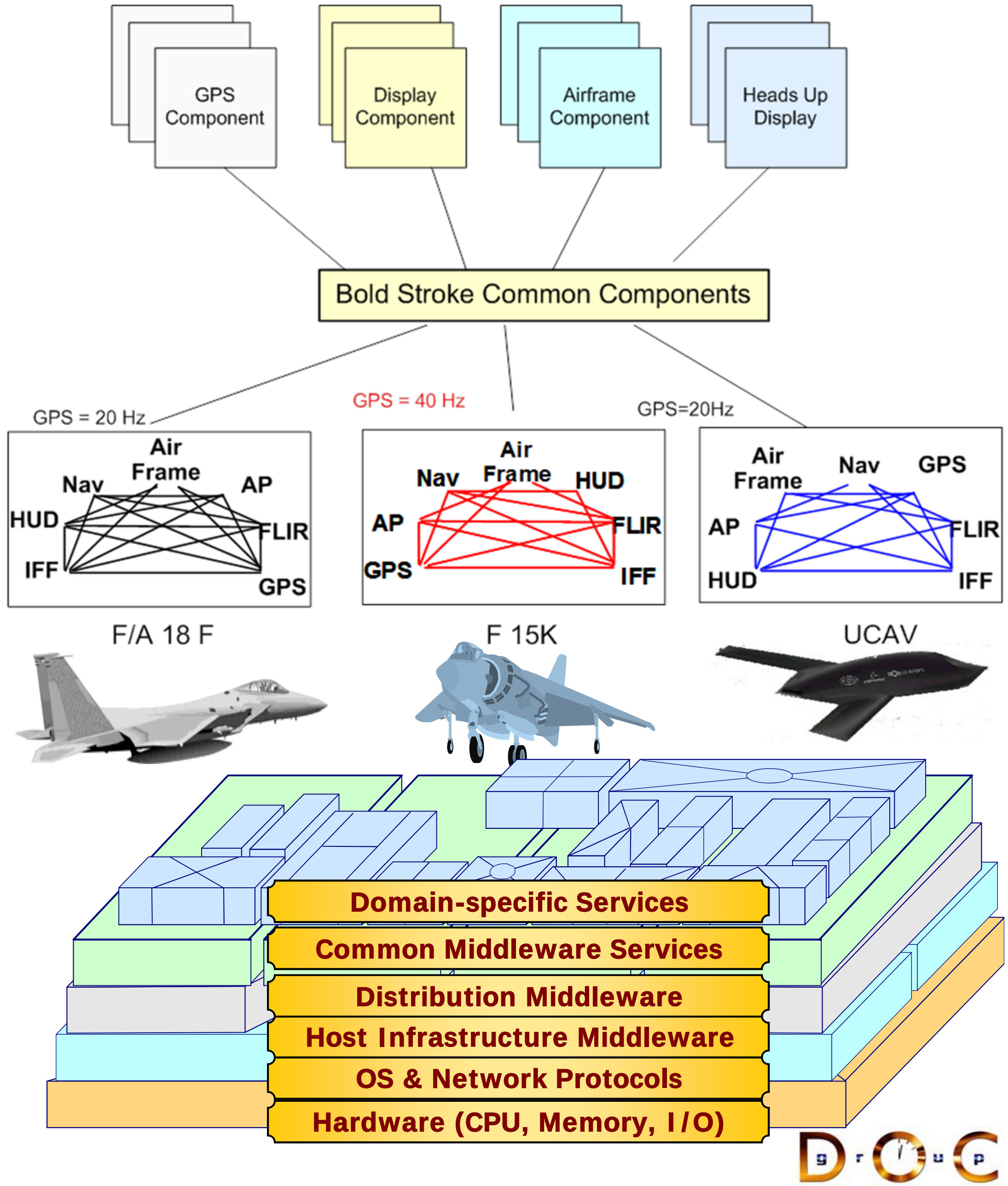


Applying SCV to the Bold Stroke SPL

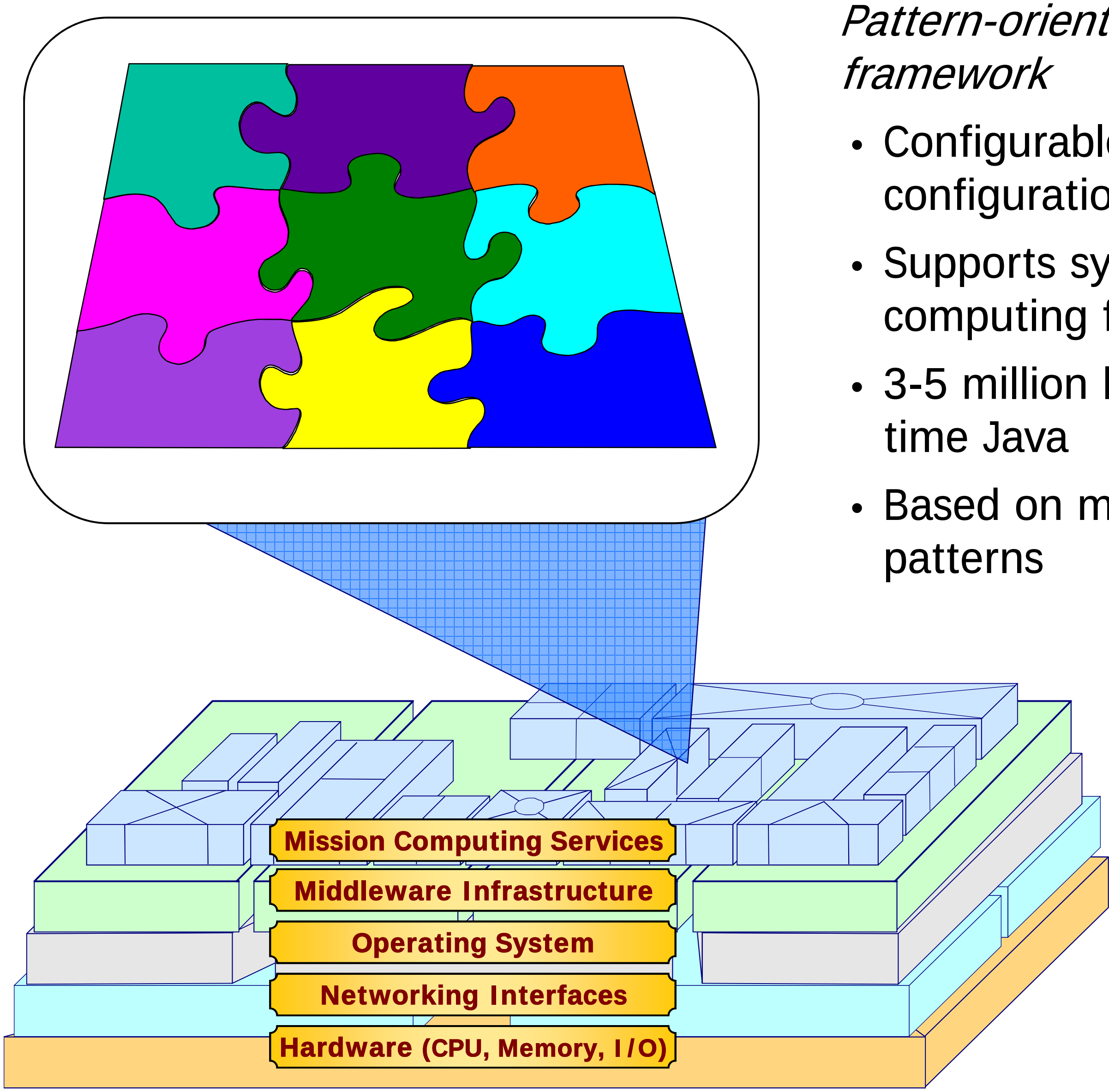
Variabilities describe the attributes unique to the different members of the family

- Product-dependent component implementations (GPS/INS)
- Product-dependent component connections
- Product-dependent component assemblies
  - e.g., different packages for different customers & countries
- Different hardware, OS, & network/bus configurations

Patterns & *frameworks* are essential for developing reusable SPLs



Applying Patterns & Frameworks to Bold Stroke



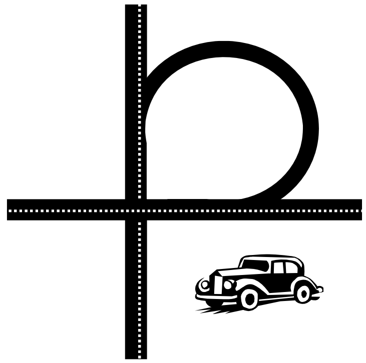
Pattern-oriented domain-specific application framework

- Configurable to variable infrastructure configurations
- Supports systematic reuse of mission computing functionality
- 3-5 million lines of C++, C, Ada, & Real-time Java
- Based on many architecture & design patterns

Patterns & frameworks are also used throughout Bold Stroke COTS software infrastructure

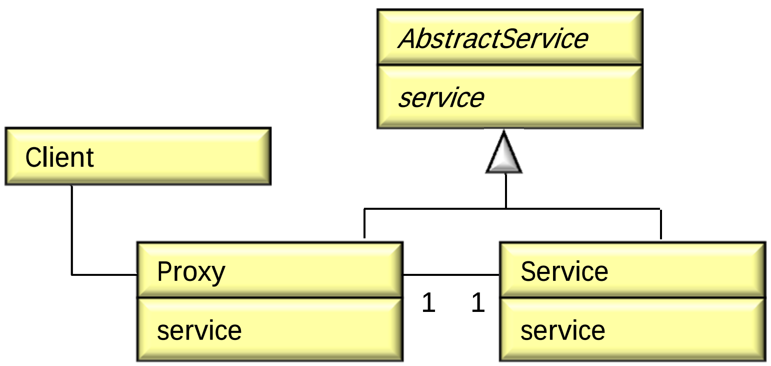
Overview of Patterns

- Present *solutions* to common software *problems* arising within a particular *context*



- Help resolve key software design forces
  - *Flexibility*
  - *Extensibility*
  - *Dependability*
  - *Predictability*
  - *Scalability*
  - *Efficiency*

- Capture recurring structures & dynamics among software participants to facilitate reuse of successful designs



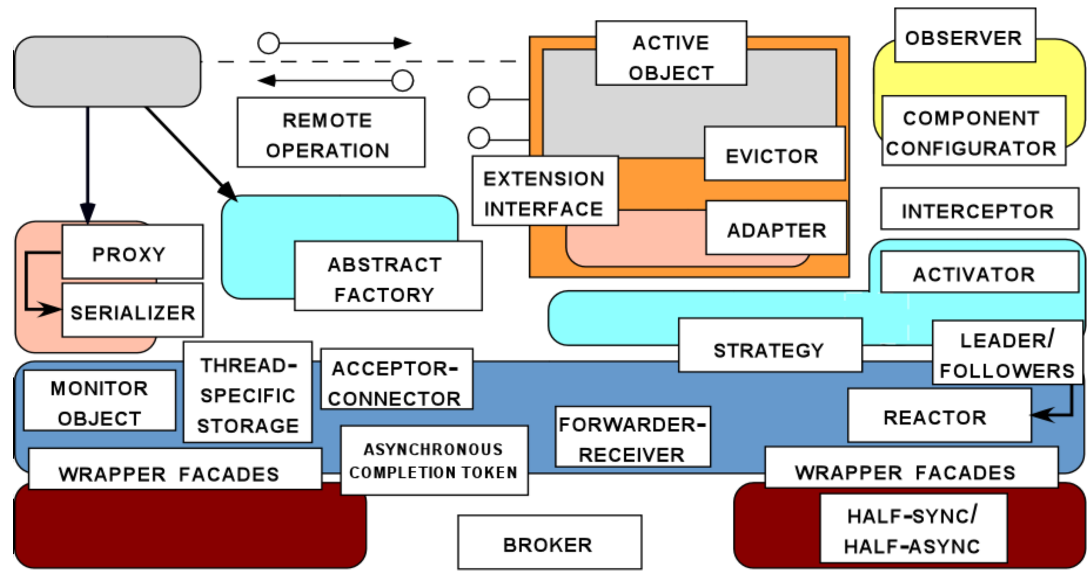
The Proxy Pattern

- Codify expert knowledge of design strategies, constraints, & best practices

Overview of Pattern Languages

Motivation

- Individual patterns & pattern catalogs are insufficient
- Software modeling methods & tools largely just illustrate *what/how* – not *why* – systems are designed



Benefits of Pattern Languages

- Define a *vocabulary* for talking about software development problems
- Provide a *process* for the orderly resolution of these problems
- Help to generate & reuse software *architectures*

Legacy Avionics Architectures

Key system characteristics

- Hard & soft real-time deadlines
  - ~20-40 Hz
- Low latency & jitter between boards
  - ~100 *u*secs
- Periodic & aperiodic processing
- Complex dependencies
- Continuous platform upgrades

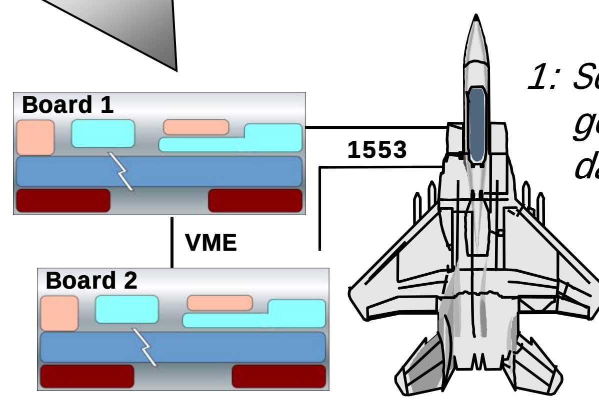
Avionics Mission Computing Functions

- Weapons targeting systems (WTS)
- Airframe & navigation (Nav)
- Sensor control (GPS, IFF, FLIR)
- Heads-up disSPLy (HUD)
- Auto-pilot (AP)

4: Mission functions perform avionics operations

3: Sensor proxies process data & pass to missions functions

2: I/O via interrupts



1: Sensors generate data

Legacy Avionics Architectures

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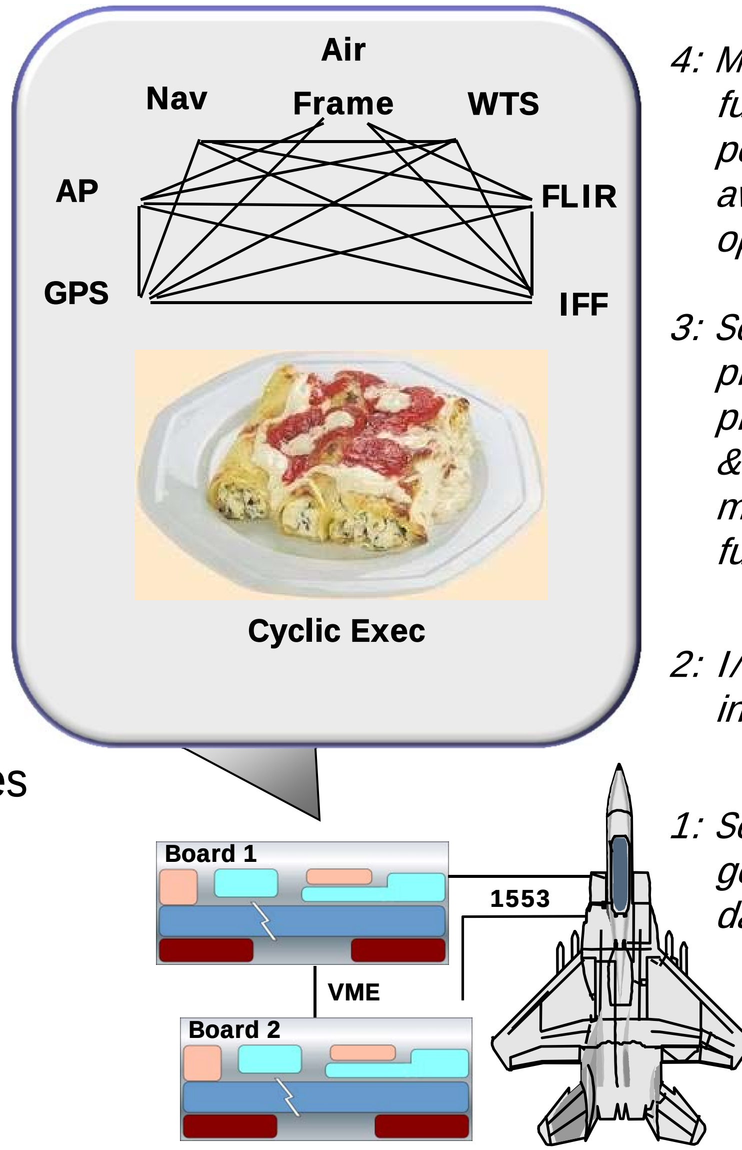


4: Mission functions perform avionics operations

3: Sensor proxies process data & pass to missions functions

2: I/O via interrupts

1: Sensors generate data

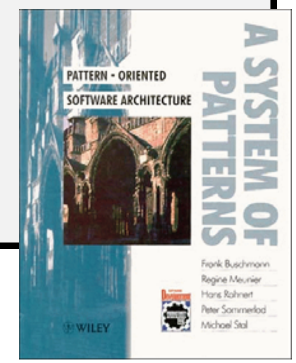
Limitations with legacy avionics architectures

- Stovepiped
- Proprietary
- Expensive
- Vulnerable

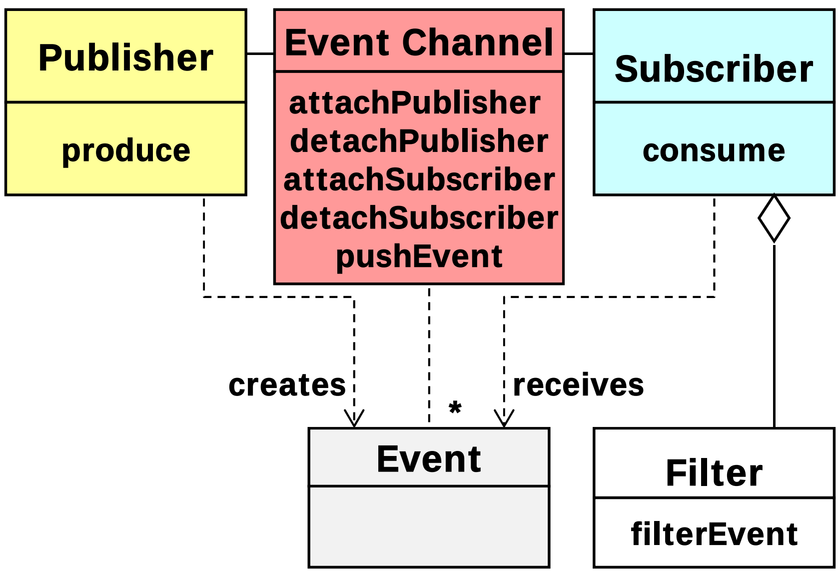
- *Tightly coupled*
- *Hard to schedule*
- *Brittle & non-adaptive*

Decoupling Avionics Components

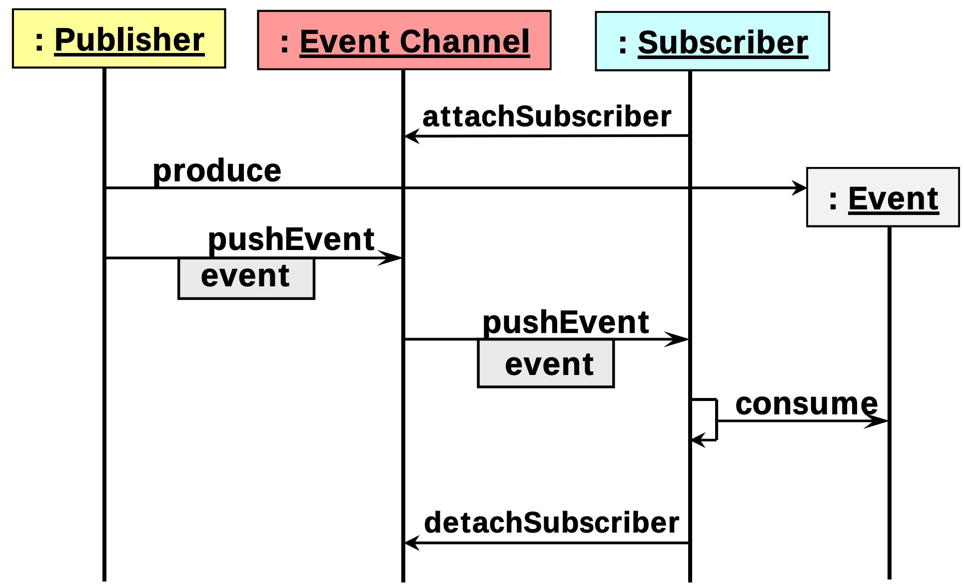
Context	Problems	Solution
• I/O driven DRE application • Complex dependencies • Real-time constraints	• Tightly coupled components • Hard to schedule • Expensive to evolve	• Apply the *Publisher-Subscriber* architectural pattern to distribute periodic, I/O-driven data from a single point source to a collection consumers



Structure



Dynamics



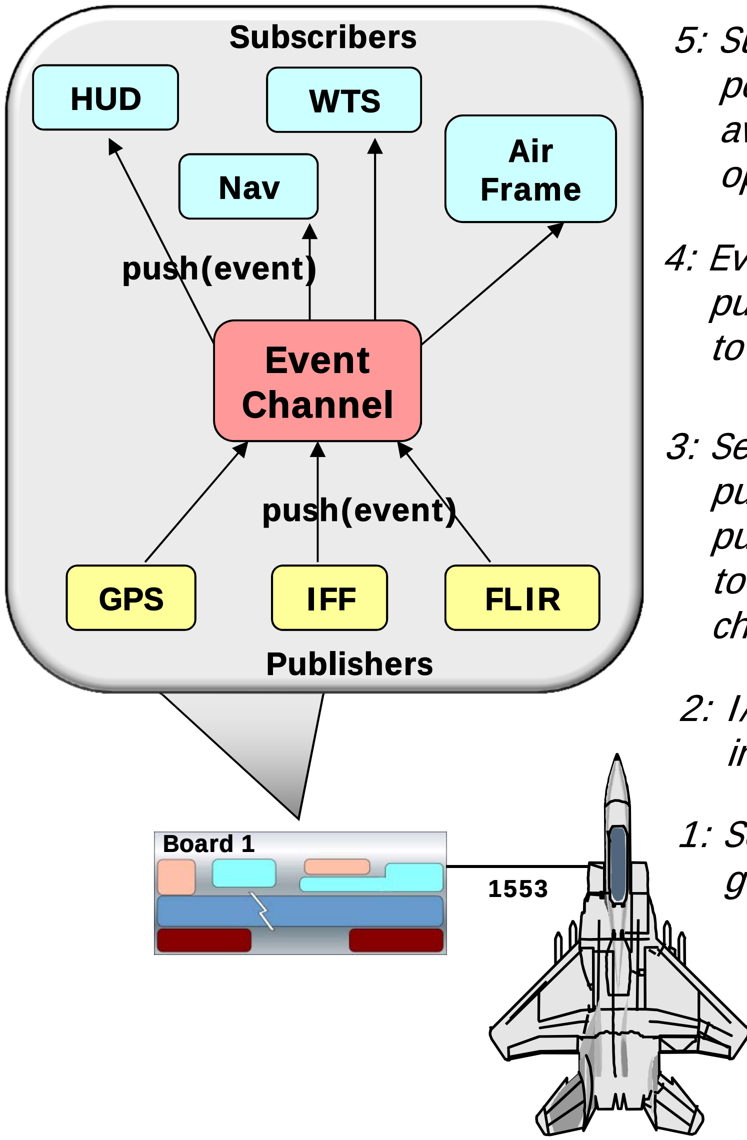
Applying Publisher-Subscriber to Bold Stroke

Bold Stroke uses the *Publisher-Subscriber* pattern to decouple sensor processing from mission computing operations

- Anonymous publisher & subscriber relationships
- Group communication
- Asynchrony

Implementing *Publisher-Subscriber* pattern for mission computing:

- *Event notification model*
  - Push control vs. pull data interactions
- *Scheduling & synchronization strategies*
  - e.g., priority-based dispatching & preemption
- *Event dependency management*
  - e.g., filtering & correlation mechanisms



5: Subscribers perform avionics operations

4: Event Channel pushes events to subscribers(s)

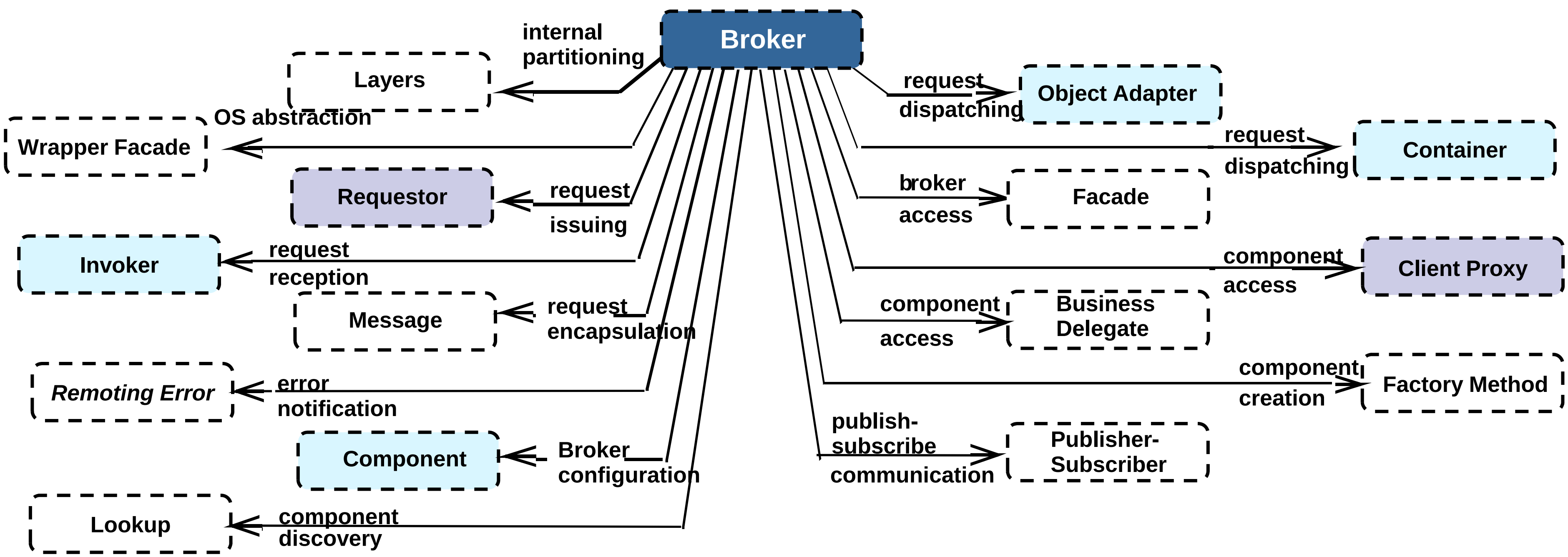
3: Sensor publishers push events to event channel

2: I/O via interrupts

1: Sensors generate data

Distributing Avionics Components

Context	Problems	Solution
• Mission computing requires remote IPC • Stringent DRE requirements	• Applications need capabilities to: • Support remote communication • Provide location transparency • Handle faults • Manage end-to-end QoS • Encapsulate low-level system details	• Apply the ***Broker*** architectural pattern to provide platform-neutral communication between mission computing boards



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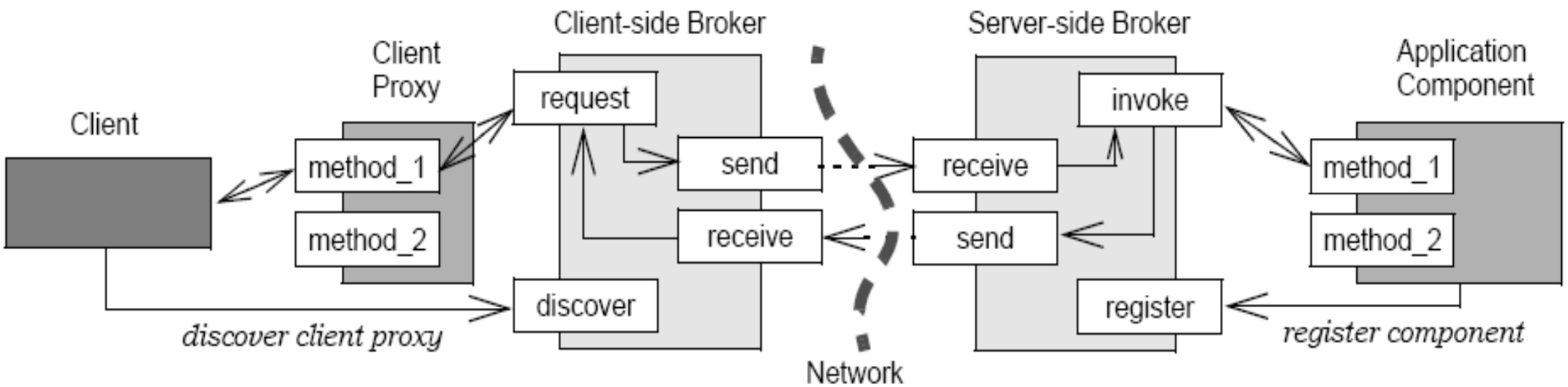
Structure & Dynamics



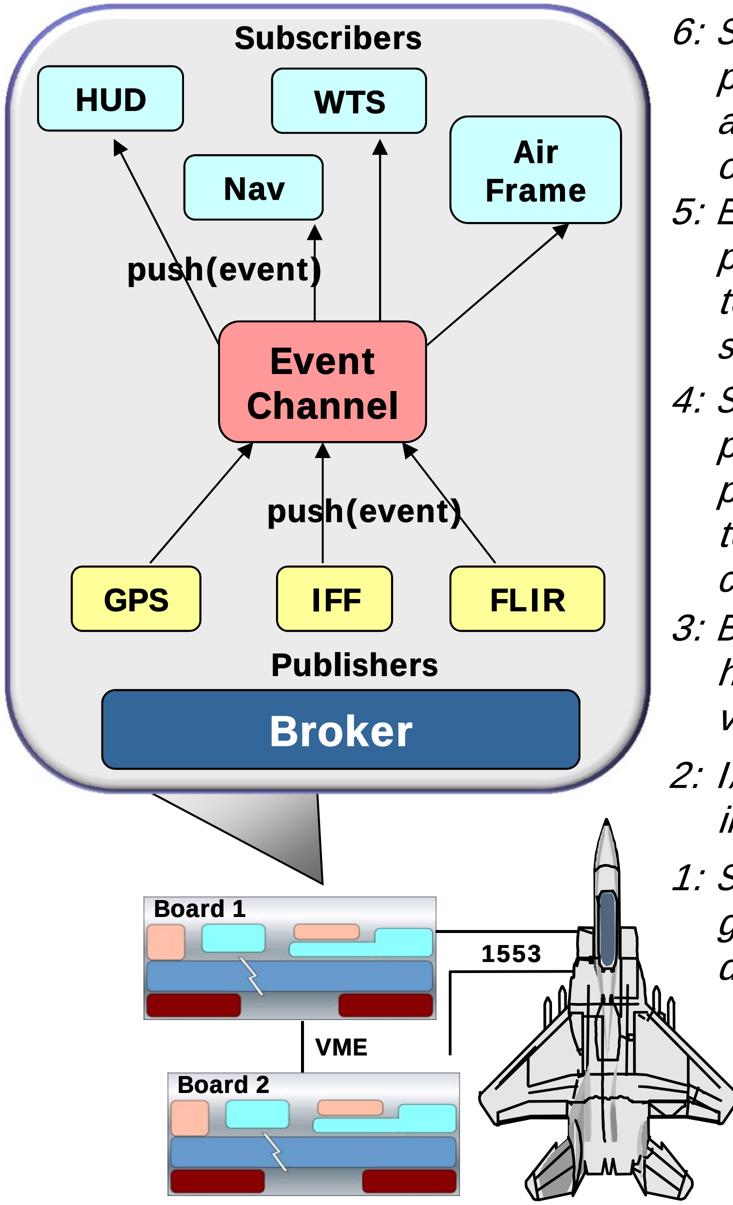
Applying the Broker Pattern to Bold Stroke

Bold Stroke uses the *Broker* pattern to shield distributed applications from environment heterogeneity, *e.g.,*

- Programming languages
- Operating systems
- Networking protocols
- Hardware

A key consideration for implementing the *Broker* pattern for mission computing applications is *QoS* support

- e.g., latency, jitter, priority preservation, dependability, security, etc.



6: Subscribers perform avionics operations

5: Event Channel pushes events to subscribers(s)

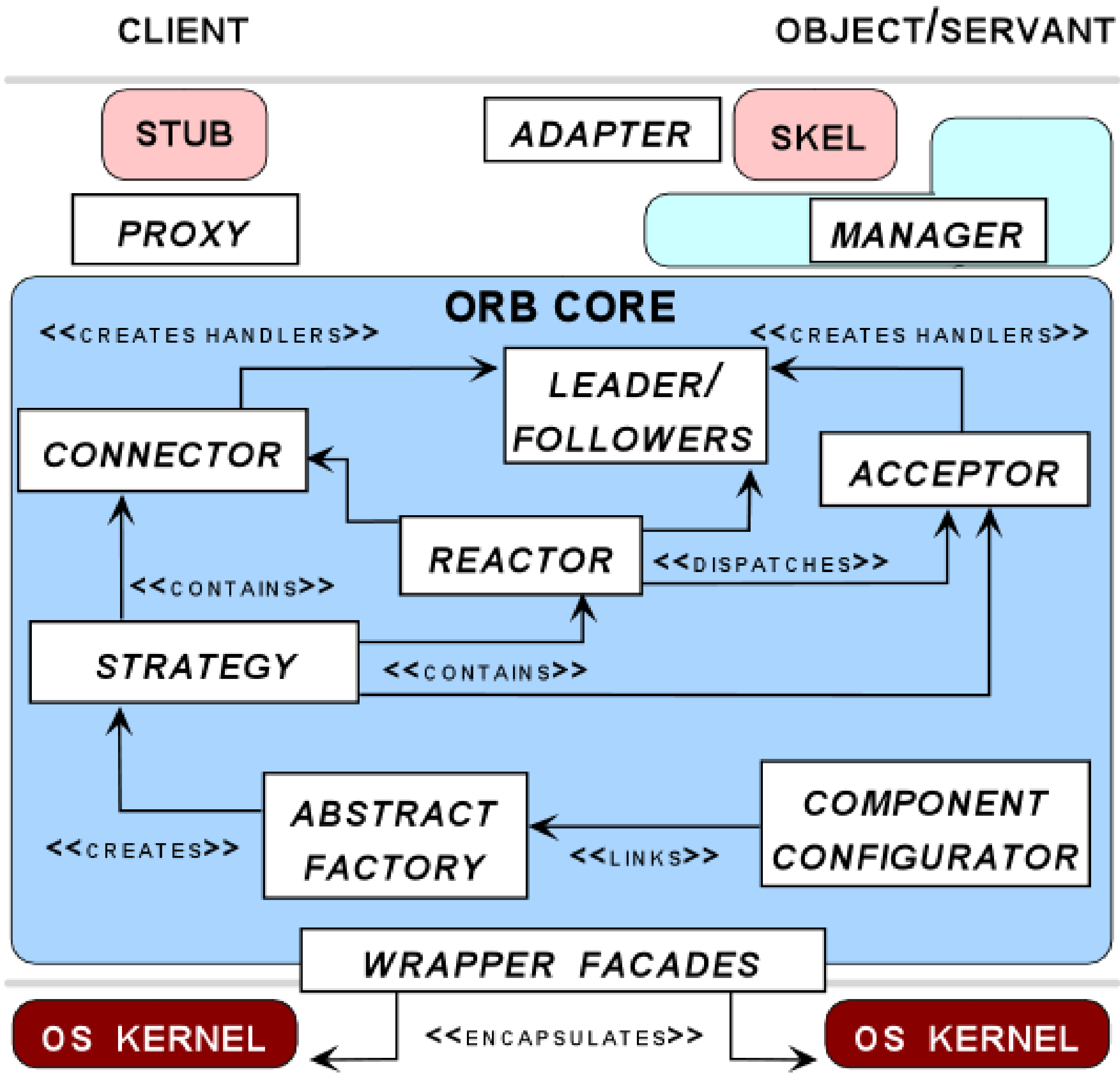
4: Sensor publishers push events to event channel

3: Broker handles I/O via upcalls

2: I/O via interrupts

1: Sensors generate data

Key Patterns Used to Implement Broker

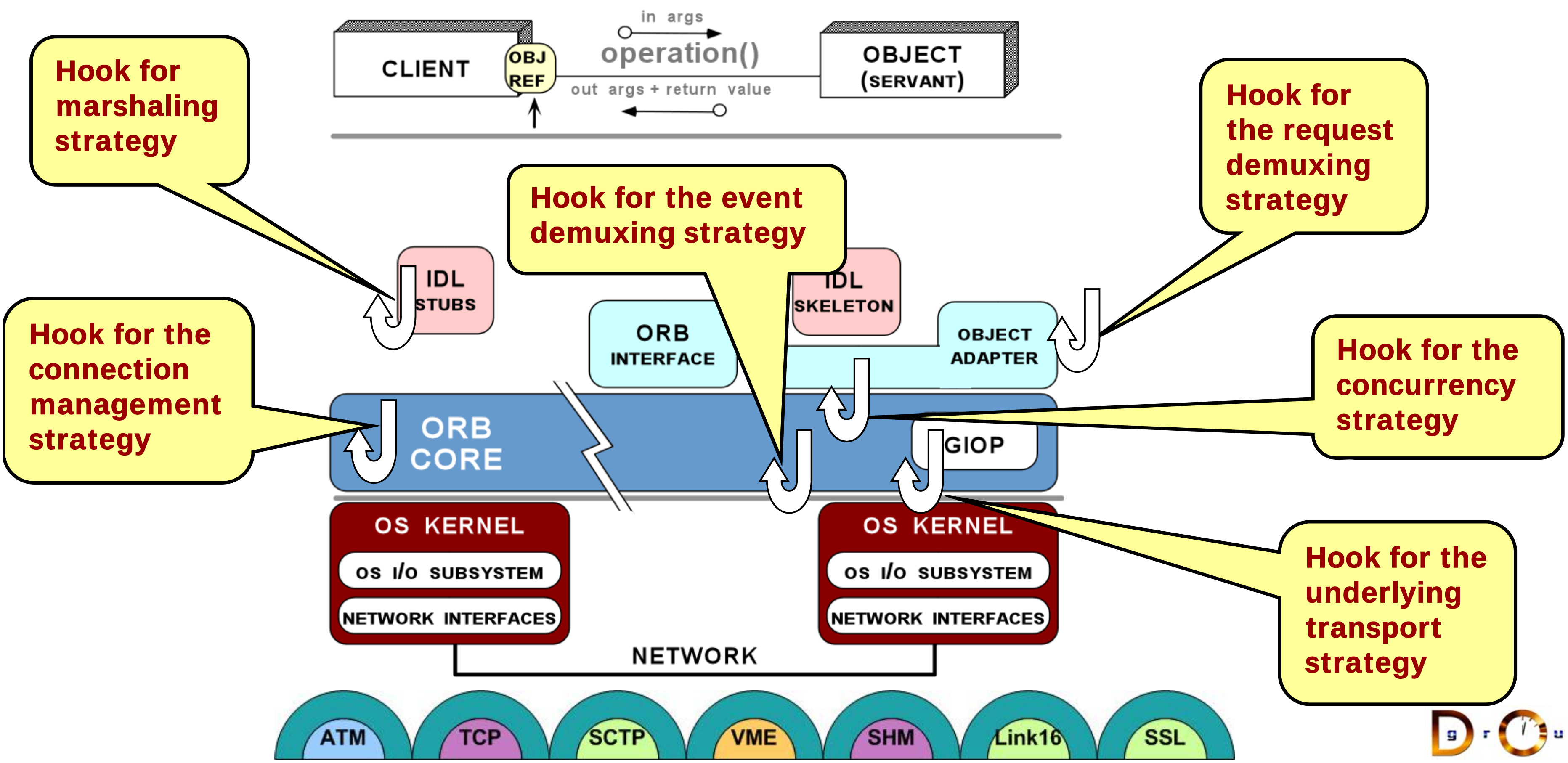


- *Wrapper facades* enhance portability
- *Proxies & adapters* simplify client & server applications, respectively
- *Component Configurator* dynamically configures *Factories*
- *Factories* produce *Strategies*
- *Strategies* implement interchangeable policies
- Concurrency strategies use *Reactor* & *Leader/Followers*
- *Acceptor-Connector* decouples connection management from request processing
- *Managers* optimize request demultiplexing

www.dre.vanderbilt.edu/~schmidt/PDF/ORB-patterns.pdf

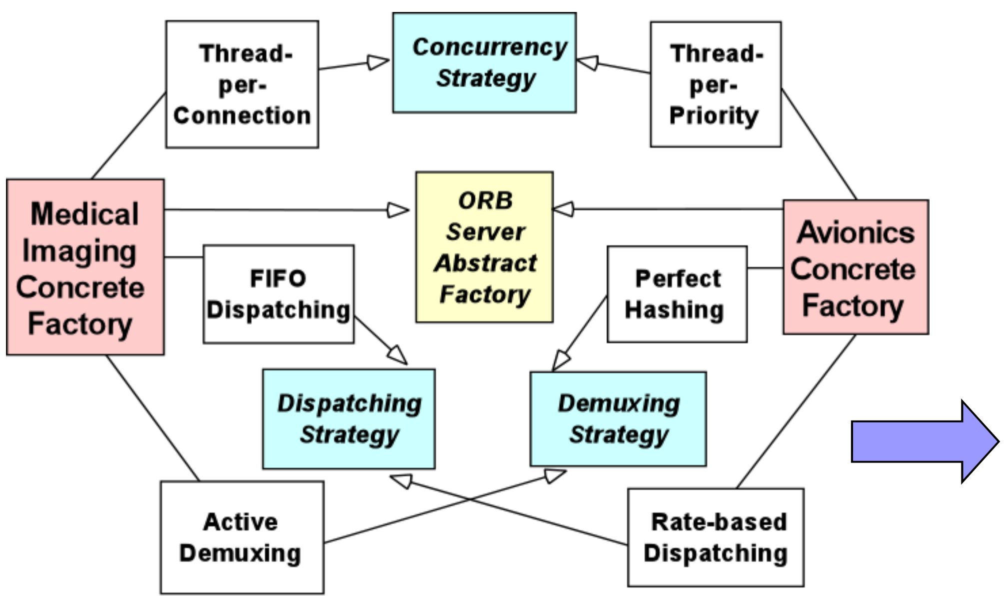
Enhancing Broker Flexibility with Strategy

Context	Problem	Solution
• Multi-domain reusable middleware Broker	• Flexible Brokers must support multiple policies for event & request demuxing, scheduling, (de)marshaling, connection mgmt, request transfer, & concurrency	• Apply the ***Strategy*** pattern to factory out commonality amongst variable Broker algorithms & policies

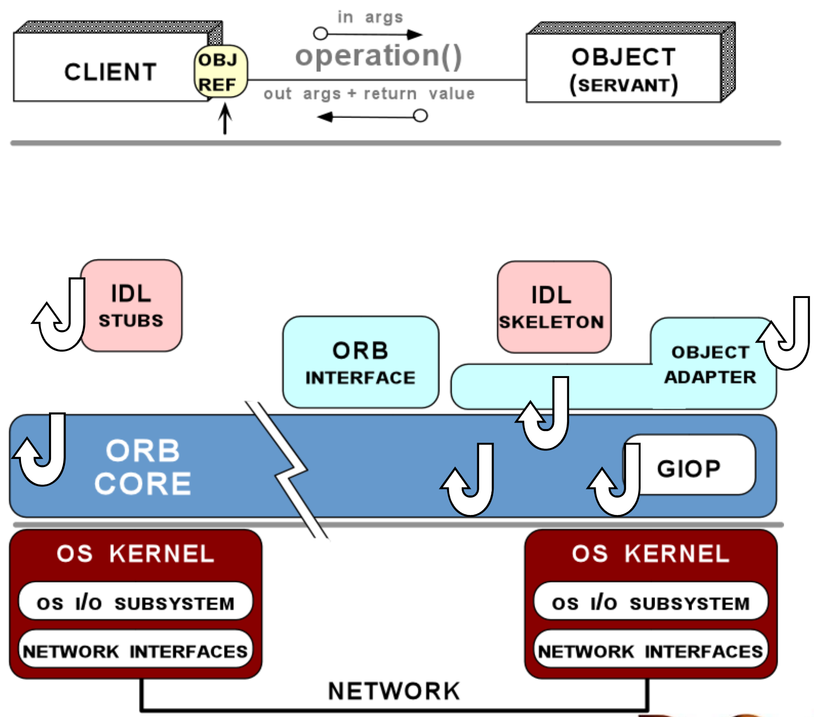


Consolidating Strategies with Abstract Factory

Context	Problem	Solution
• A heavily strategized framework or application	• Aggressive use of Strategy pattern creates a configuration nightmare • Managing many individual strategies is hard • It's hard to ensure that groups of semantically compatible strategies are configured	• Apply the ***Abstract Factory*** pattern to consolidate multiple Broker strategies into semantically compatible configurations

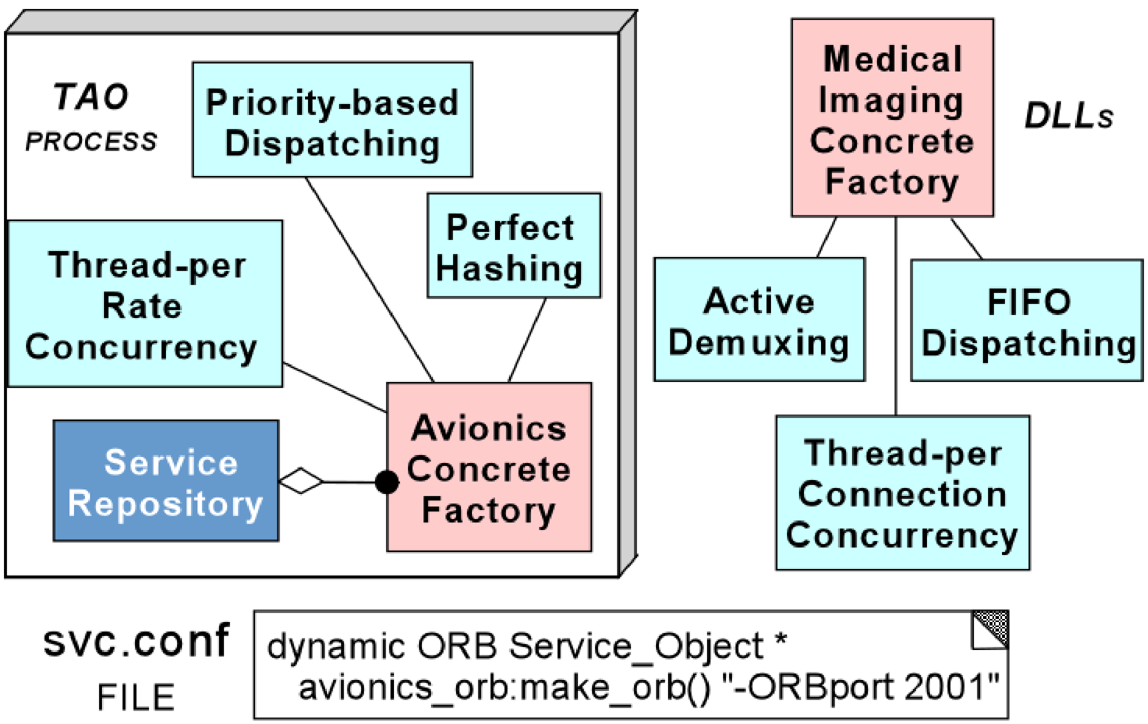


Concrete factories create groups of strategies



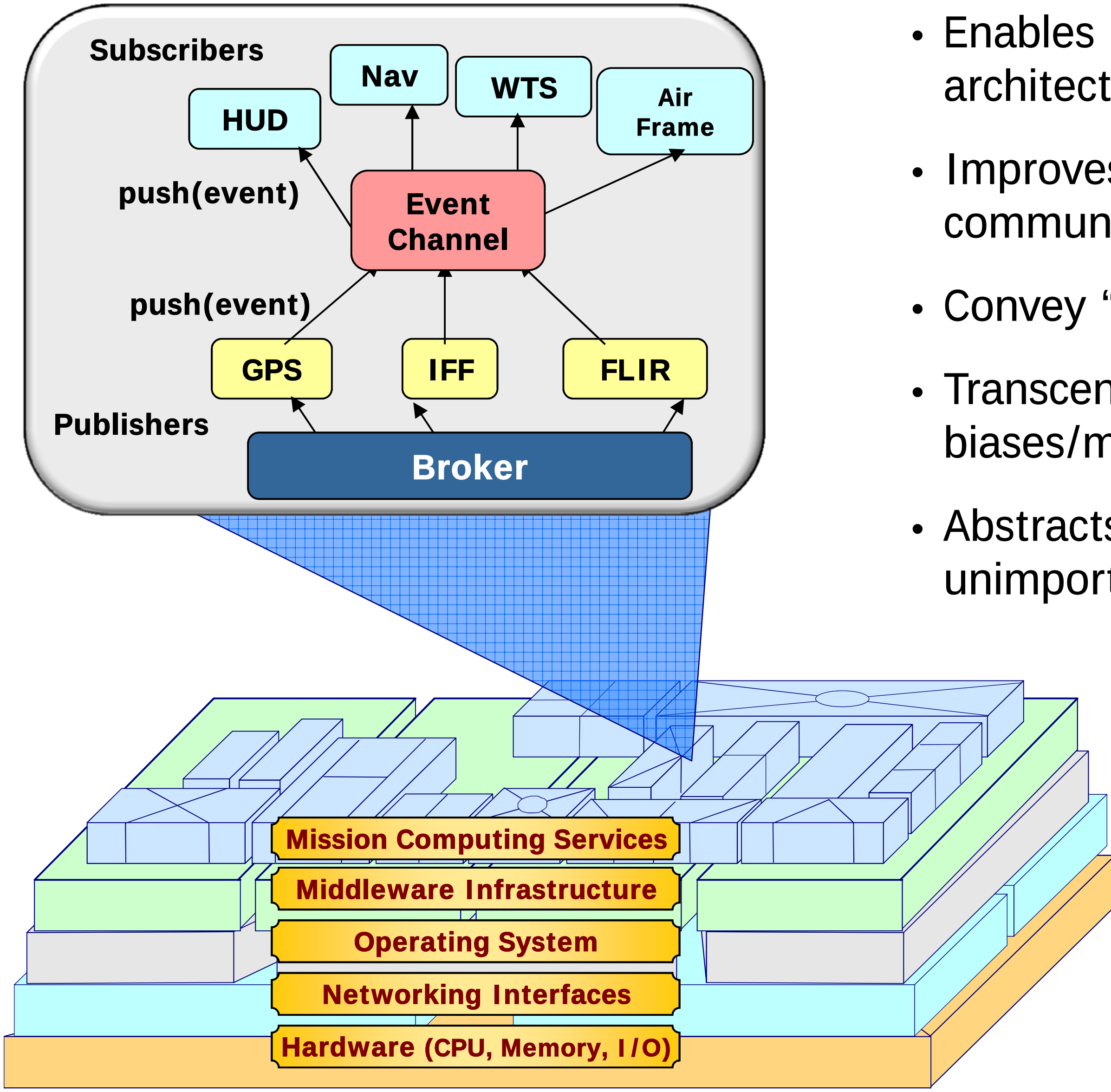
Configuring Factories w/ Component Configurator

Context	Problem	Solution
• Resource constrained systems	• Prematurely commiting to a Broker configuration is inflexible & inefficient • Certain decisions can't be made until runtime • Users forced to pay for components they don't use	• Apply the ***Component Configurator*** pattern to assemble the desired Broker factories & strategies more effectively



- Broker strategies are decoupled from when the strategy implementations are configured into Broker
- This pattern can reduce the memory footprint of Broker implementations

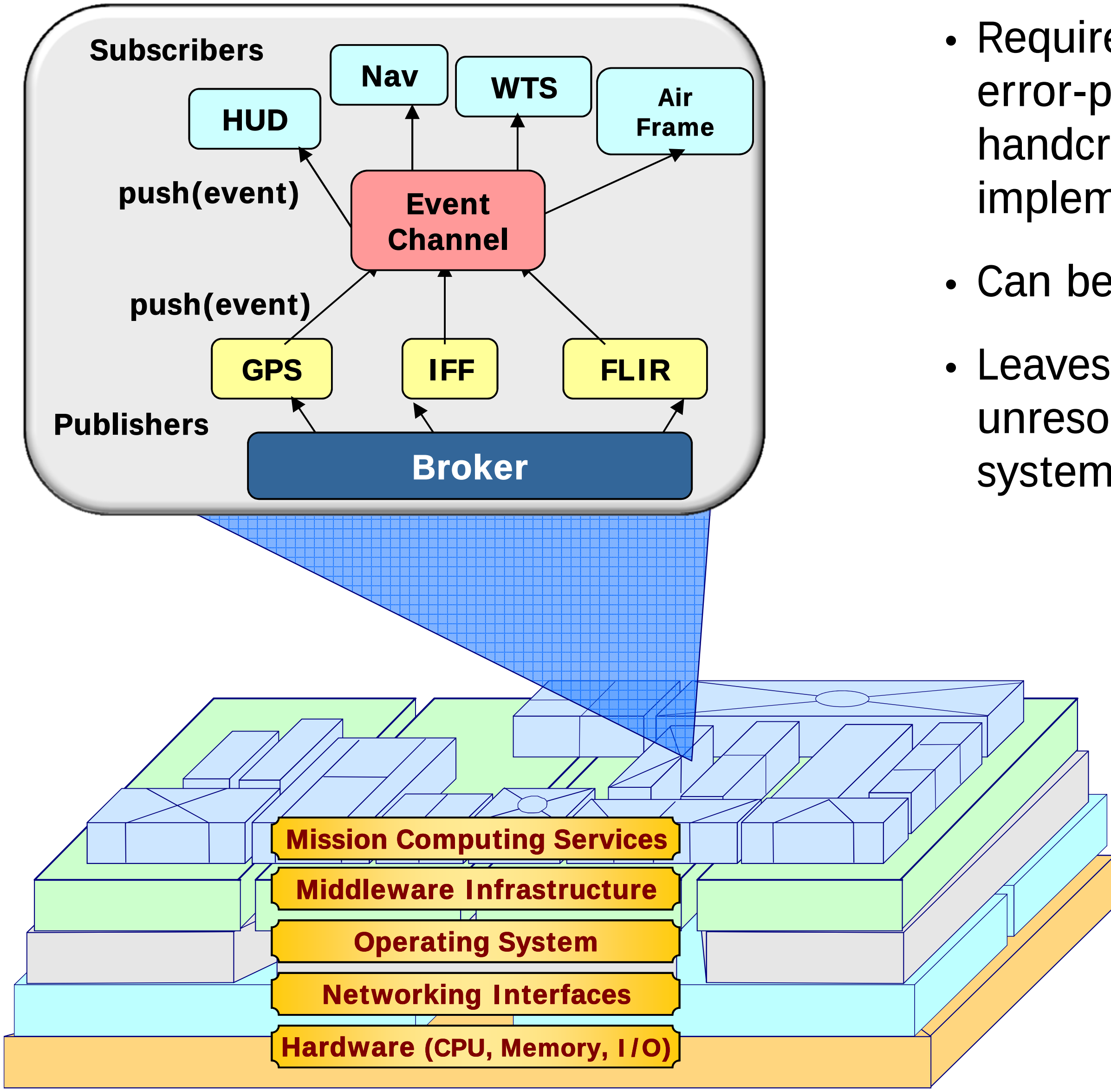
Benefits of Patterns



- Enables reuse of software architectures & designs
- Improves development team communication
- Convey "best practices" intuitively
- Transcends language-centric biases/myopia
- Abstracts away from many unimportant details

www.dre.vanderbilt.edu/~schmidt/patterns.html

Limitations of Patterns

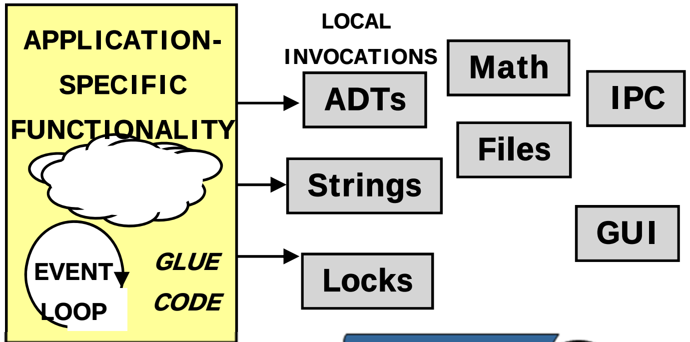


- Require significant tedious & error-prone human effort to handcraft pattern implementations
- Can be deceptively simple
- Leaves many important details unresolved, particularly for DRE systems

We therefore need more than just patterns to achieve effective systematic reuse

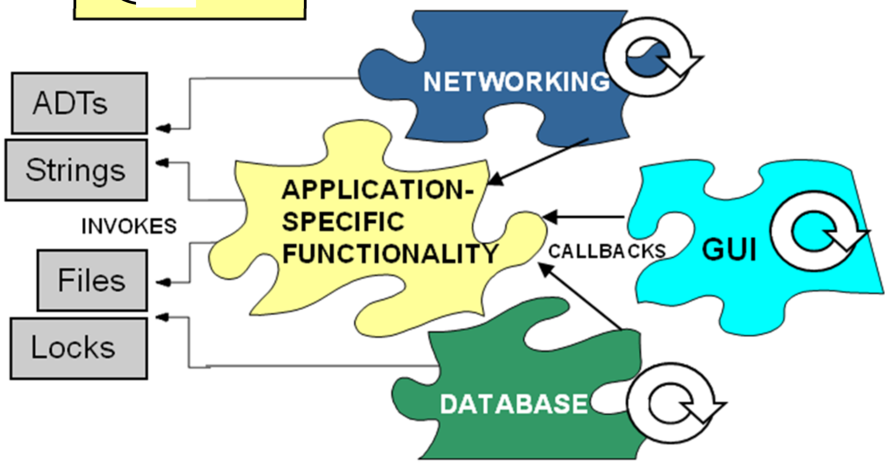
www.dre.vanderbilt.edu/~schmidt/patterns.html

Overview of Systematic Reuse Paradigms



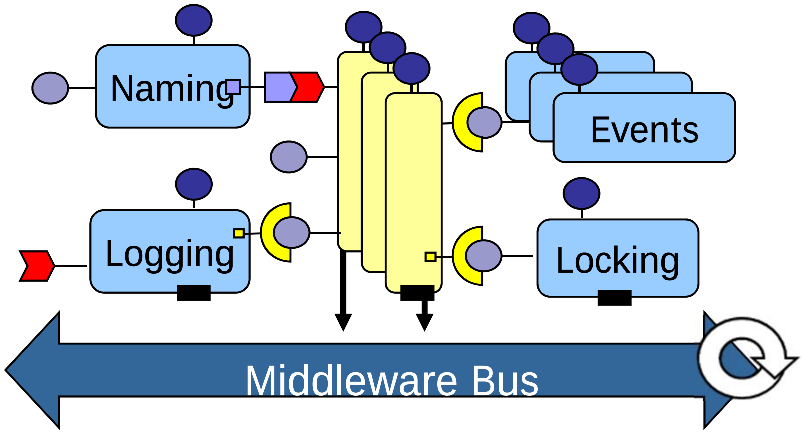
Class Library Architecture

- A *class* is a unit of abstraction & implementation in an OO programming language, i.e., a reusable *type* that often implements *patterns*
- Classes are typically *passive*



Framework Architecture

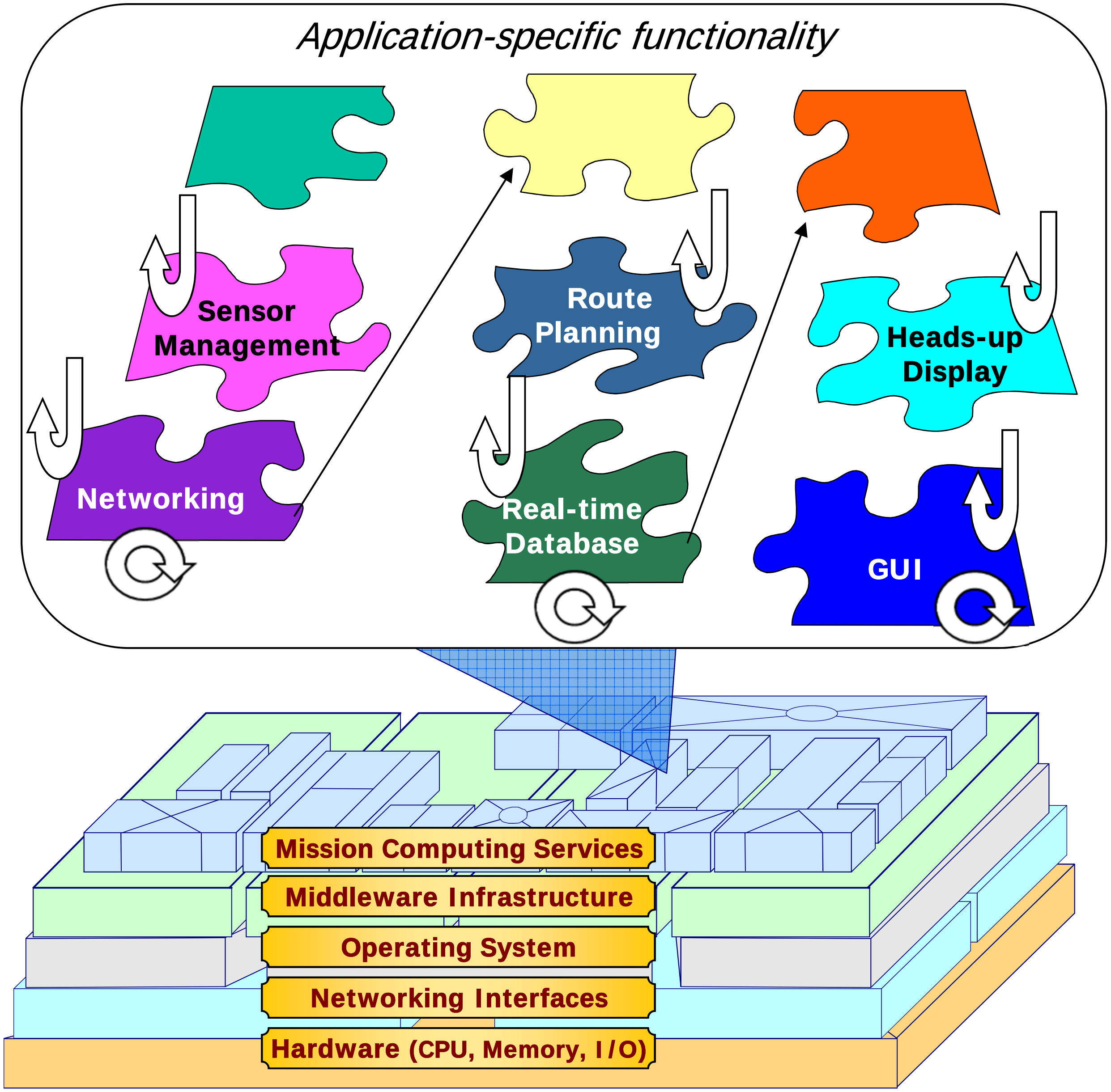
- A *framework* is an integrated set of classes that collaborate to produce a reusable architecture for a family of applications
- Frameworks implement *pattern languages*



Component / Service-Oriented Architecture

- A *component/service* is an encapsulation unit with one or more interfaces that provide clients with access to its services
- Components/services can be deployed & configured via *assemblies*

Applying Frameworks to Bold Stroke



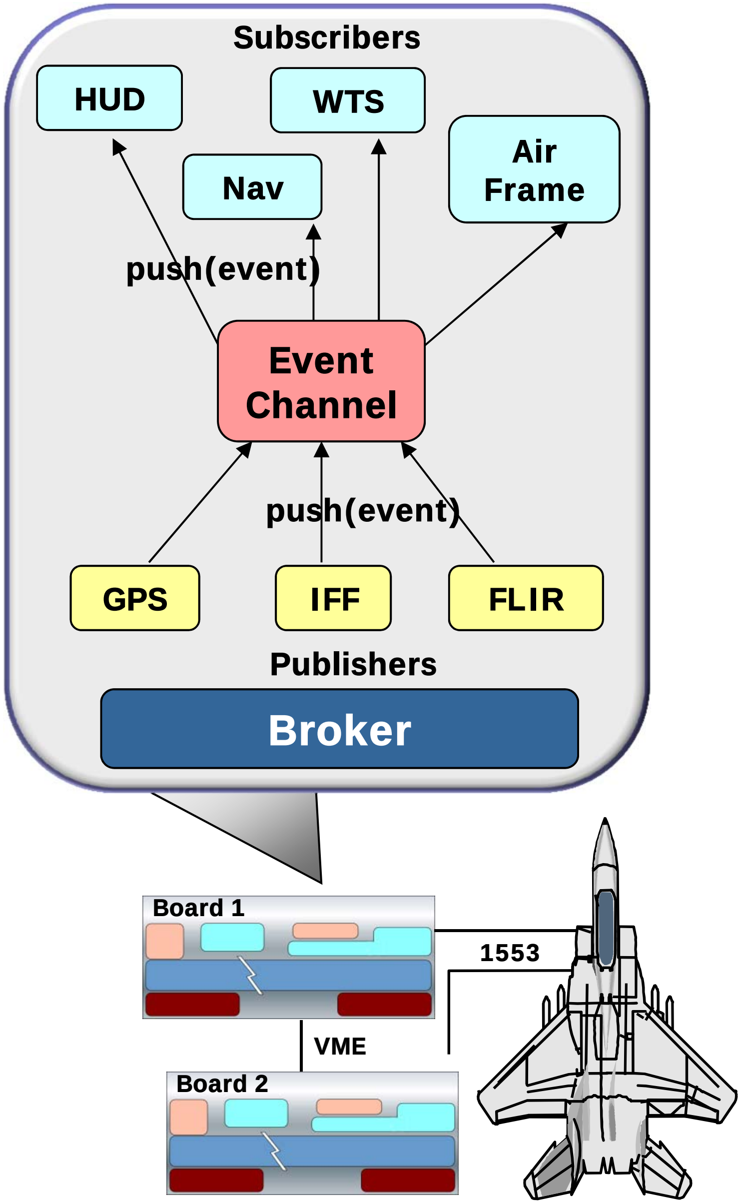
Framework characteristics

- Frameworks exhibit "inversion of control" at runtime via callbacks
- Frameworks provide integrated domain-specific structures & functionality
- Frameworks are "semi-complete" applications

www.dre.vanderbilt.edu/~schmidt/frameworks.html

Benefits of Frameworks

- Design reuse
  - e.g., by implementing patterns that guide application developers through the steps necessary to ensure successful creation & deployment of avionics software



Benefits of Frameworks

- Design reuse
  - e.g., by implementing patterns that guide application developers through the steps necessary to ensure successful creation & deployment of avionics software
- Implementation reuse
  - e.g., by amortizing software lifecycle costs & leveraging previous development & optimization efforts

```java
package org.apache.tomcat.session;

import org.apache.tomcat.core.*;
import org.apache.tomcat.util.StringManager;
import java.io.*;
import java.net.*;
import java.util.*;
import javax.servlet.*;
import javax.servlet.http.*;

/**
 * Core implementation of a server session
 *
 * @author James Duncan Davidson [duncan@eng.sun.com]
 * @author James Todd [gonzo@eng.sun.com]
 */

public class ServerSession {

    private StringManager sm =
        StringManager.getManager("org.apache.tomcat.session");
    private Hashtable values = new Hashtable();
    private Hashtable appSessions = new Hashtable();
    private String id;
    private long creationTime = System.currentTimeMillis();;
    private long thisAccessTime = creationTime;
    private int inactiveInterval = -1;

    ServerSession(String id) { this.id = id; }

    public String getId() { return id; }

    public long getCreationTime() { return creationTime; }


    public ApplicationSession getApplicationSession(Context context,
        boolean create) {
        ApplicationSession appSession =
            (ApplicationSession)appSessions.get(context);

        if (appSession == null && create) {

            // XXX
            // sync to ensure valid?

            appSession = new ApplicationSession(id, this, context);
            appSessions.put(context, appSession);
        }

        // XXX
        // make sure that we haven't gone over the end of our
        // inactive interval -- if so, invalidate & create
        // a new appSession

        return appSession;
    }

    void removeApplicationSession(Context context) {
        appSessions.remove(context);
    }
```

Benefits of Frameworks

- Design reuse
  - e.g., by implementing patterns that guide application developers through the steps necessary to ensure successful creation & deployment of avionics software
- Implementation reuse
  - e.g., by amortizing software lifecycle costs & leveraging previous development & optimization efforts
- Validation reuse
  - e.g., by amortizing the efforts of validating application- & platform-independent portions of software, thereby enhancing software reliability & scalability

Build Scoreboard

Doxygen

Build Name	Last Finished	Config	Setup	Compile	Tests	Status
Doxygen	Sep 05, 2002 - 03:24	[Config]	[Full]	[Full] [Brief]		Inactive

Linux

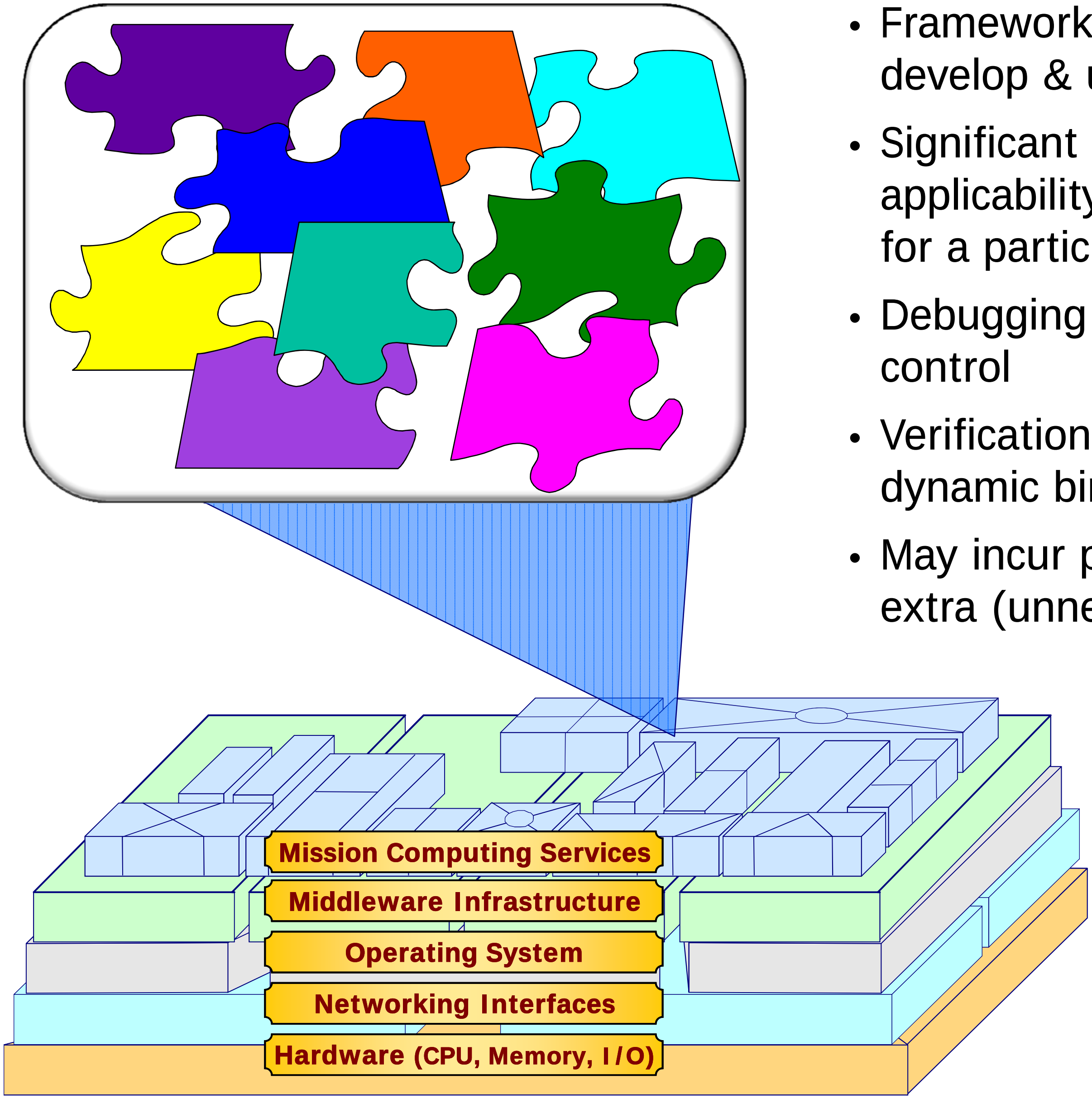
Build Name	Last Finished	Config	Setup	Compile	Tests	Status
Debian_Core	Sep 05, 2002 - 14:36	[Config]	[Full]	[Full]		Inactive
Debian_Full	Sep 05, 2002 - 12:19	[Config]	[Full]	[Full] [Brief]	[Full] [Brief]	Inactive
Debian_Full_Reactors	Sep 05, 2002 - 11:59	[Config]	[Full]	[Full] [Brief]	[Full] [Brief]	Inactive
Debian_GCC_3.0.4	Sep 05, 2002 - 13:45	[Config]	[Full]	[Full] [Brief]	[Full] [Brief]	Compile
Debian_Minimum	Sep 05, 2002 - 08:51	[Config]	[Full]	[Full] [Brief]	[Full] [Brief]	Compile
Debian_Minimum_Static	Sep 04, 2002 - 00:53	[Config]	[Full]	[Full] [Brief]	[Full] [Brief]	Setup
Debian_NoInline	Sep 05, 2002 - 12:31	[Config]	[Full]	[Full] [Brief]	[Full] [Brief]	Compile
Debian_NoInterceptors	Sep 05, 2002 - 09:10	[Config]	[Full]	[Full] [Brief]	[Full] [Brief]	Inactive
Debian_WChar_GCC_3.1	Sep 05, 2002 - 01:23	[Config]	[Full]	[Full]	[Full] [Brief]	Compile
RedHat_7.1_Full	Sep 04, 2002 - 02:34	[Config]	[Full]	[Full]	[Full] [Brief]	Setup
RedHat_7.1_No_AMI_Messaging	Sep 05, 2002 - 04:56	[Config]	[Full]	[Full] [Brief]	[Full] [Brief]	Compile
RedHat_Core	Sep 05, 2002 - 14:34	[Config]	[Full]	[Full] [Brief]	[Full] [Brief]	Compile
RedHat_Explicit_Templates	Sep 05, 2002 - 08:56	[Config]	[Full]	[Full] [Brief]	[Full] [Brief]	Inactive
RedHat_GCC_3.2	Sep 05, 2002 - 06:53	[Config]	[Full]	[Full] [Brief]	[Full] [Brief]	Inactive
RedHat_Implicit_Templates	Sep 03, 2002 - 06:25	[Config]	[Full]	[Full] [Brief]	[Full] [Brief]	Inactive
RedHat_Single_Threaded	Sep 05, 2002 - 10:55	[Config]	[Full]	[Full] [Brief]	[Full] [Brief]	Compile
RedHat_Static	Sep 05, 2002 - 15:24	[Config]	[Full]	[Full] [Brief]	[Full] [Brief]	Inactive

Lynx

Build Name	Last Finished	Config	Setup	Compile	Tests	Status
Lynx_PPC	Sep 03, 2002 - 10:58	[Config]	[Full]	[Full] [Brief]		Setup

www.dre.vanderbilt.edu/scoreboard

Limitations of Frameworks



- Frameworks are powerful, but hard to develop & use effectively
- Significant time required to evaluate applicability & quality of a framework for a particular domain
- Debugging is tricky due to inversion of control
- Verification & validation is tricky due to dynamic binding
- May incur performance overhead due to extra (unnecessary) levels of indirection

We thus need something simpler than frameworks to achieve systematic reuse for DRE systems

www.dre.vanderbilt.edu/~schmidt/PDF/Queue-04.pdf

The Evolution of Middleware

- DRE Applications
- Domain-Specific Services
- Common Middleware Services
- Distribution Middleware
- Host Infrastructure Middleware
- Operating Systems & Protocols
- Hardware

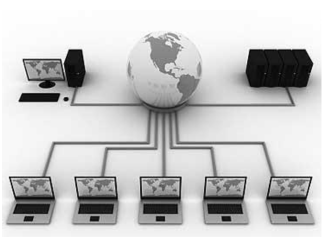
Historically, mission-critical DRE apps were built directly atop hardware & OS

- Tedious, error-prone, & costly over lifecycles

There are layers of middleware, just like there are layers of networking protocols

Standards-based COTS DRE middleware helps:

- Control end-to-end resources & QoS
- Leverage hardware & software technology advances
- Evolve to new environments & requirements
- Provide a wide array of reusable, off-the-shelf developer-oriented services

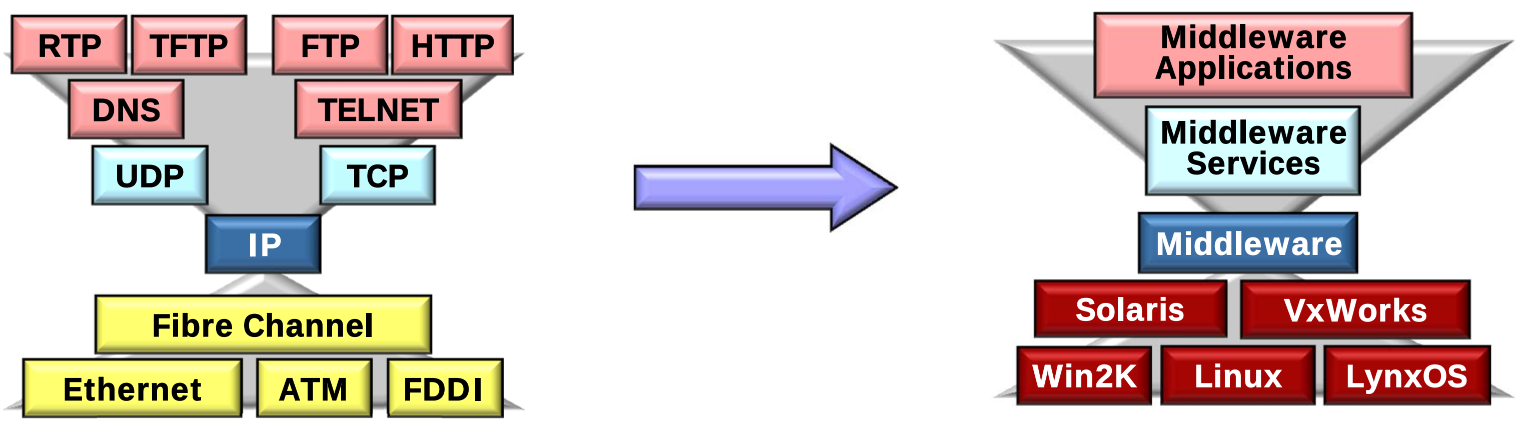


Middleware is pervasive in enterprise domain & is becoming pervasive in DRE domain

Operating System & Protocols

- Operating systems & protocols provide mechanisms to manage endsystem resources, e.g.,
  - CPU scheduling & dispatching
  - Virtual memory management
  - Secondary storage, persistence, & file systems
  - Local & remote interprocess communication (IPC)
- OS examples
  - UNIX/Linux, Windows, VxWorks, QNX, etc.
- Protocol examples
  - TCP, UDP, IP, SCTP, RTP, etc.

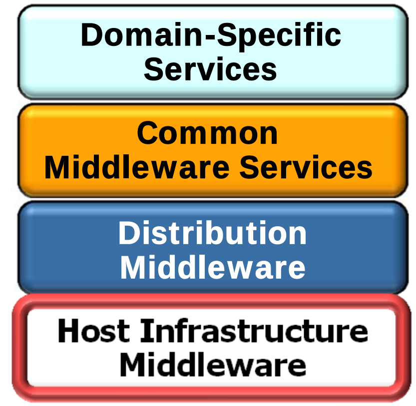
INTERNETWORKING ARCH *MIDDLEWARE ARCH*

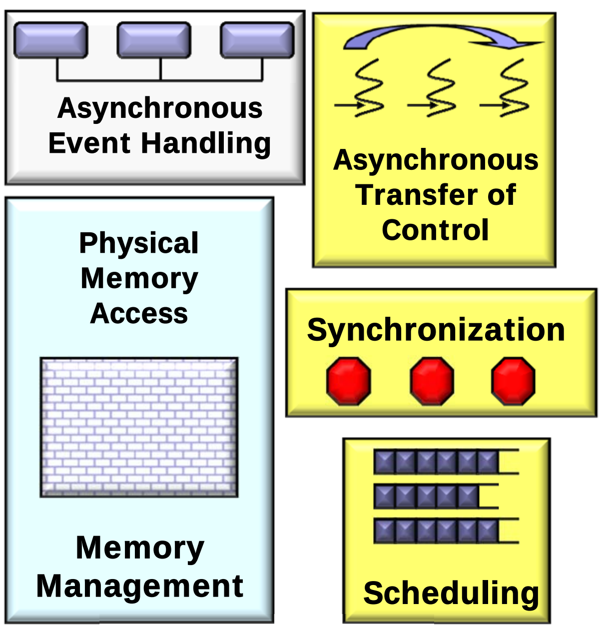


20th Century 21st Century

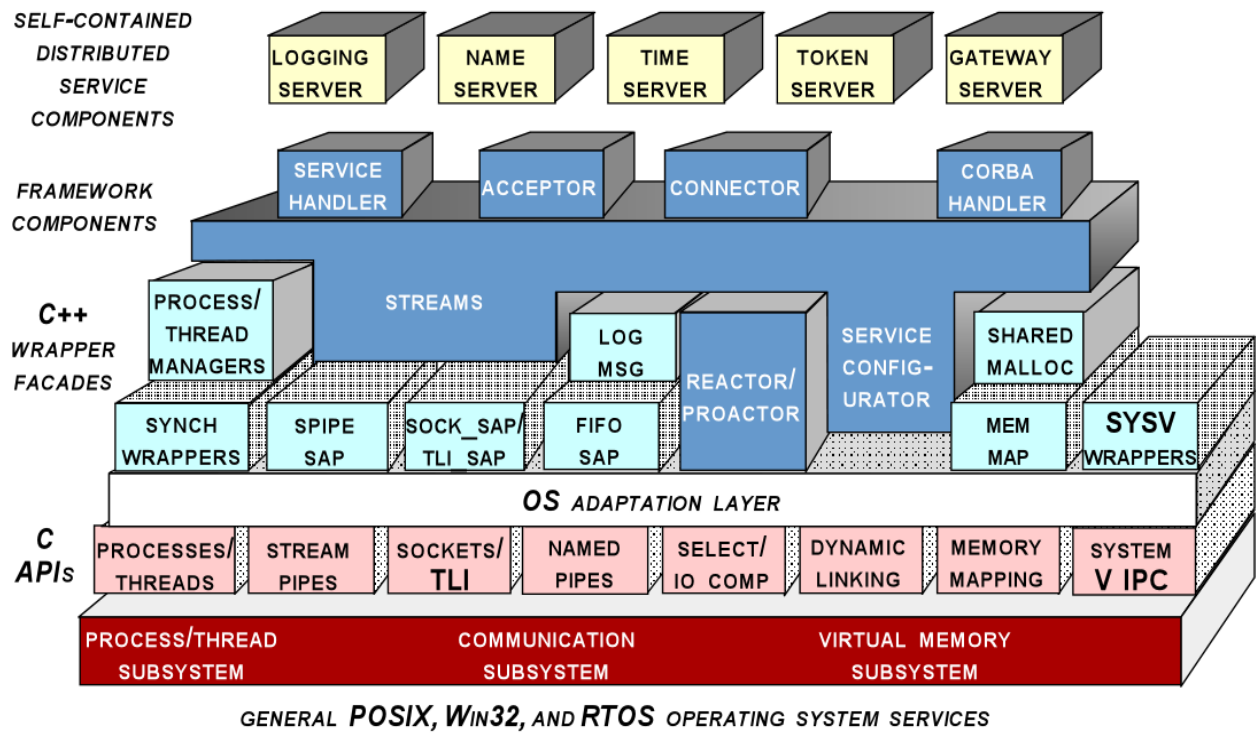
Host Infrastructure Middleware

- Host infrastructure middleware encapsulates & enhances native OS mechanisms to create reusable network programming objects
  - These components abstract away many tedious & error-prone aspects of low-level OS APIs
- Examples
  - Java Virtual Machine (JVM), Common Language Runtime (CLR), ADAPTIVE Communication Environment (ACE)





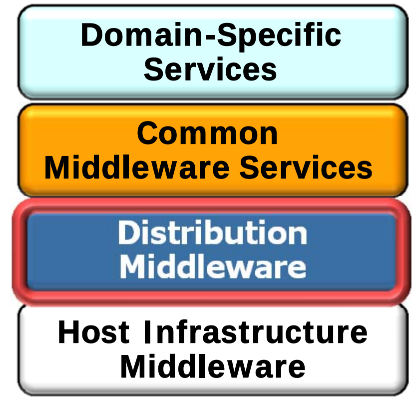
www.rtj.org



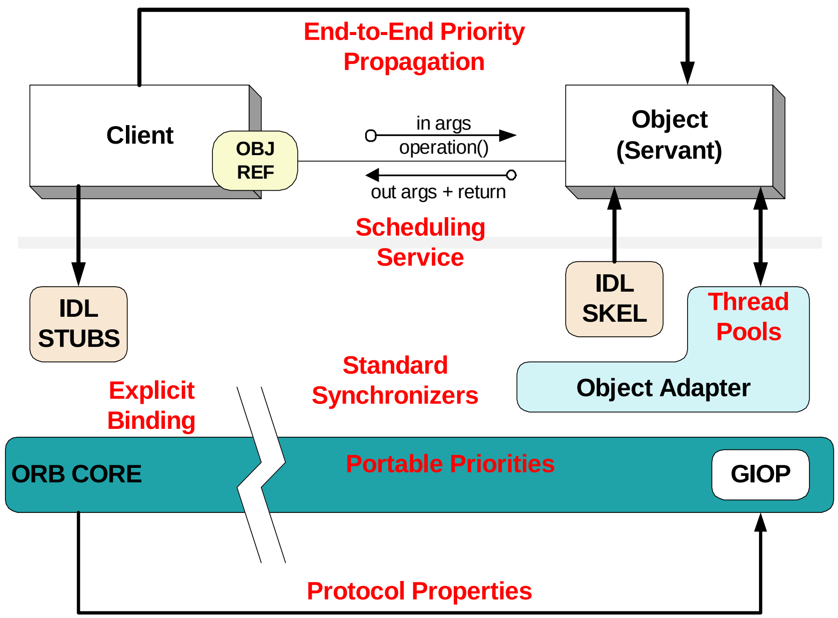
www.dre.vanderbilt.edu/~schmidt/ACE.html

Distribution Middleware

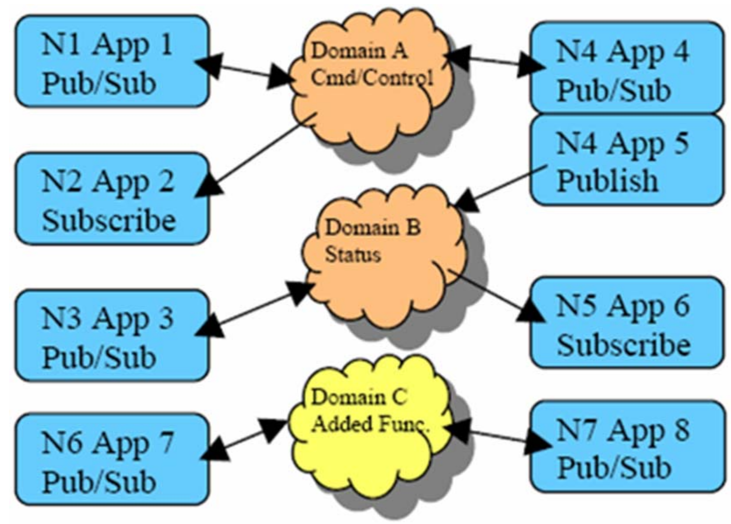
- *Distribution middleware* defines higher-level distributed programming models whose reusable APIs & components automate & extend native OS capabilities



- Examples
  - OMG Real-time CORBA & DDS, Sun RMI, Microsoft DCOM, W3C SOAP



realtime.omg.org

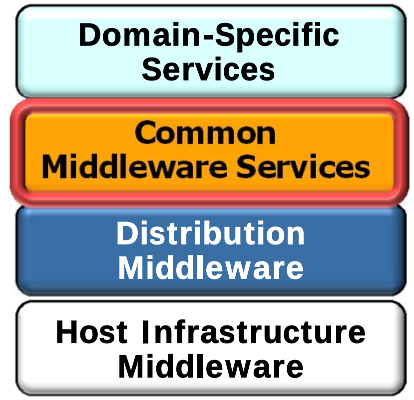


en.wikipedia.org/wiki/Data_Distribution_Service

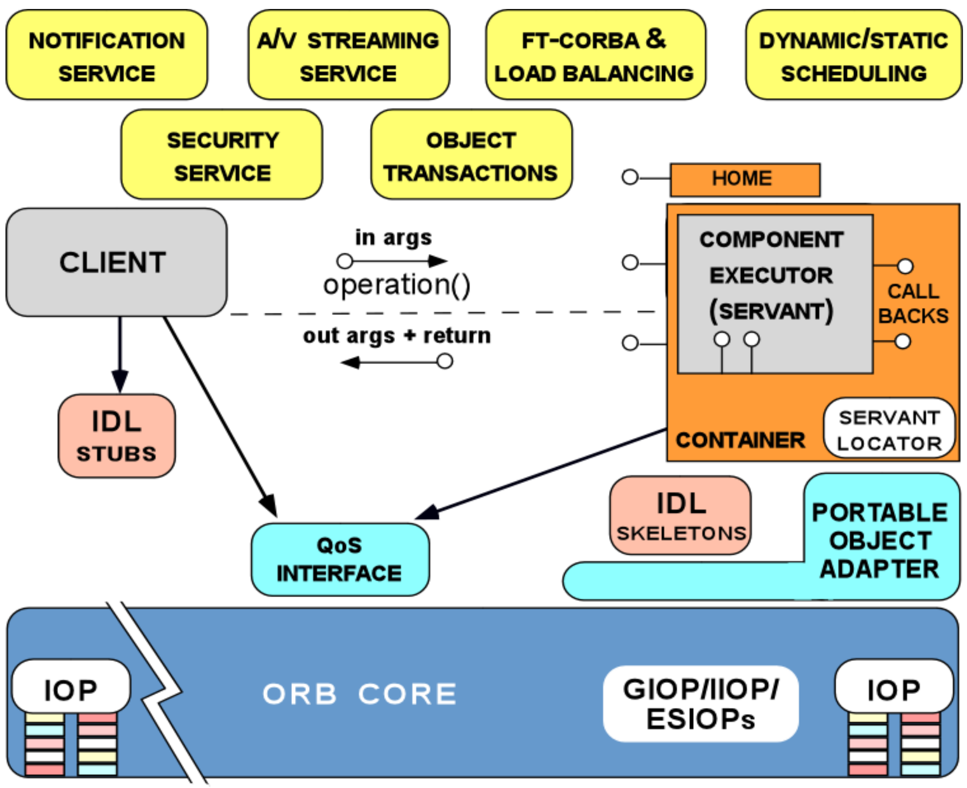
Distribution middleware avoids hard-coding client & server application dependencies on object location, language, OS, protocols, & hardware

Common Middleware Services

- *Common middleware services* augment distribution middleware by defining higher-level domain-independent services that focus on programming “business logic”

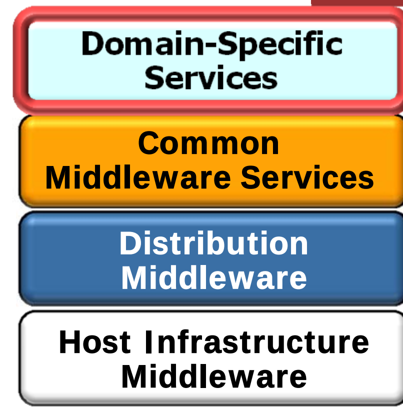


- Examples
  - W3C Web Services, CORBA Component Model & Object Services, Sun’s J2EE, Microsoft’s .NET, etc.



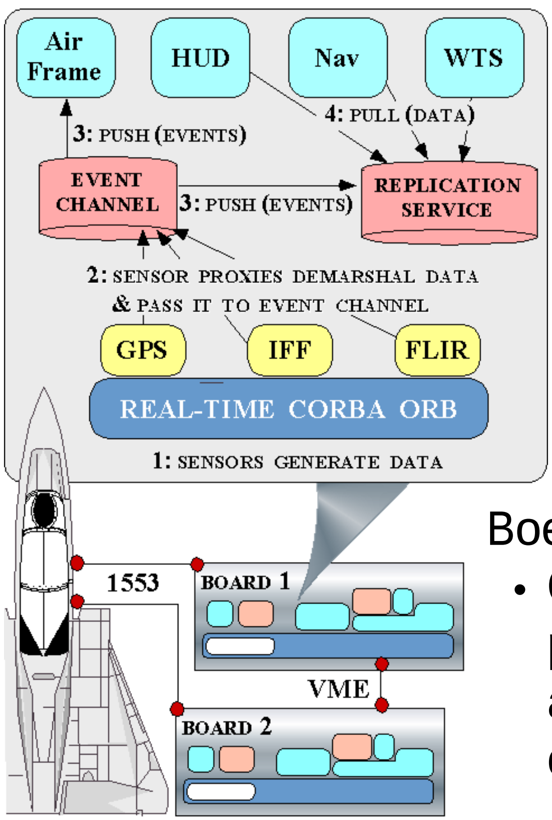
- Common middleware services support many recurring distributed system capabilities, e.g.,
  - Transactional behavior
  - Authentication & authorization,
  - Database connection pooling & concurrency control
  - Active replication
  - Dynamic resource management

Domain-Specific Middleware

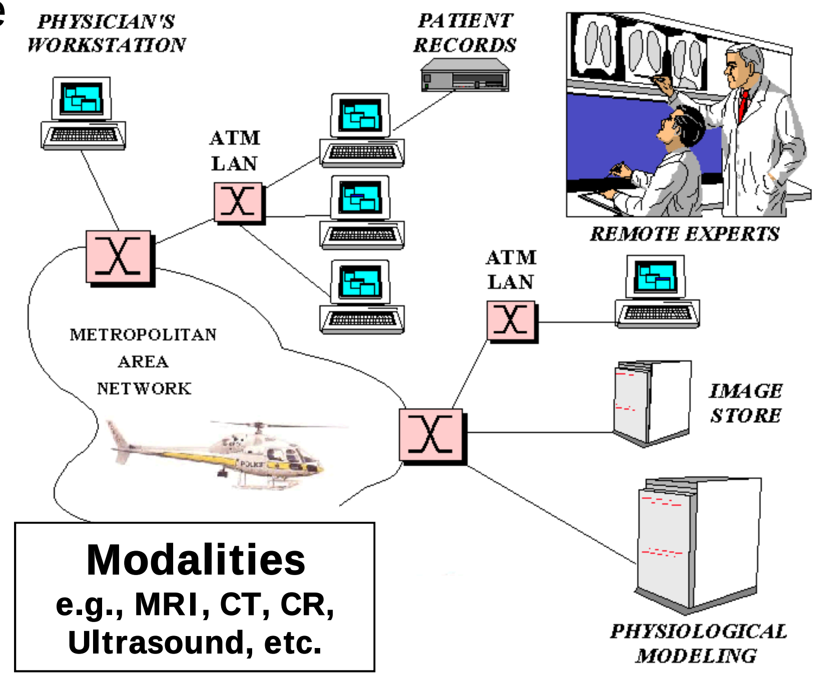


- *Domain-specific middleware services* are tailored to the requirements of particular domains, such as telecom, e-commerce, health care, process automation, or aerospace

- Examples

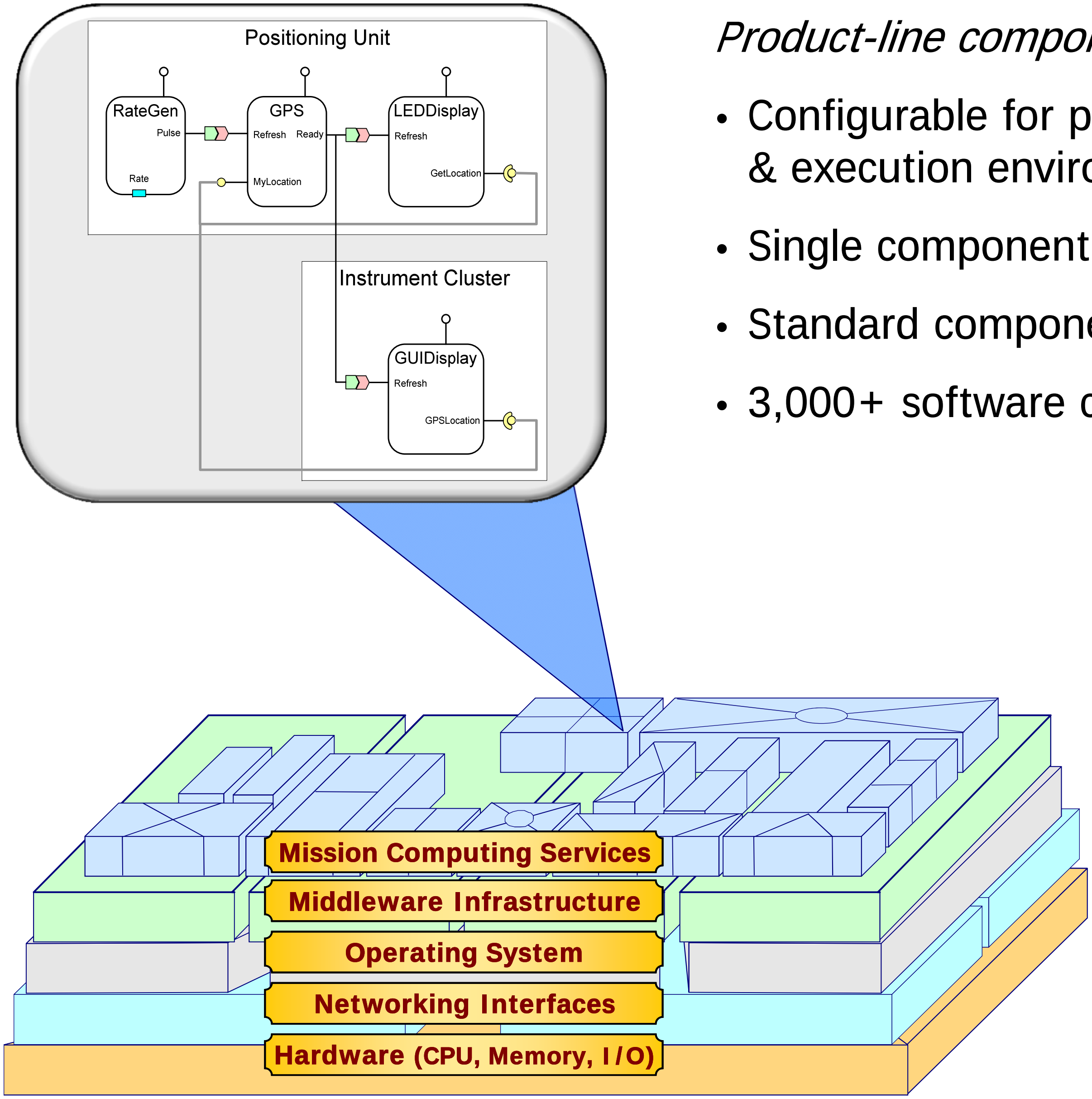


Siemens MED Syngo
- Common software platform for distributed electronic medical systems
- Used by all Siemens MED business units worldwide



Boeing Bold Stroke
- Common software platform for Boeing avionics mission computing systems

Applying Component Middleware to Bold Stroke

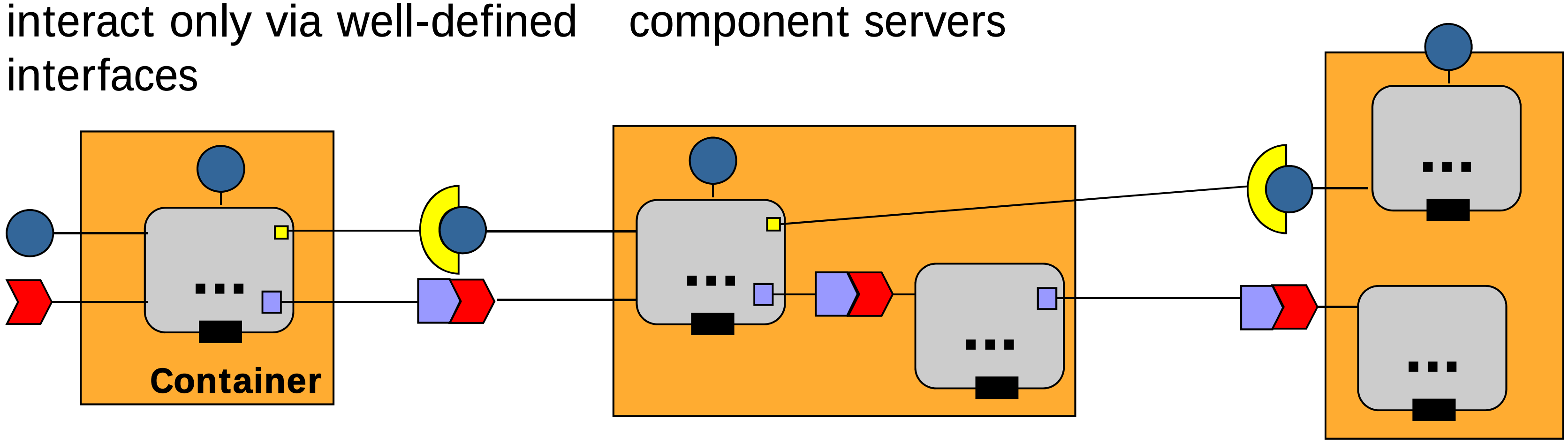


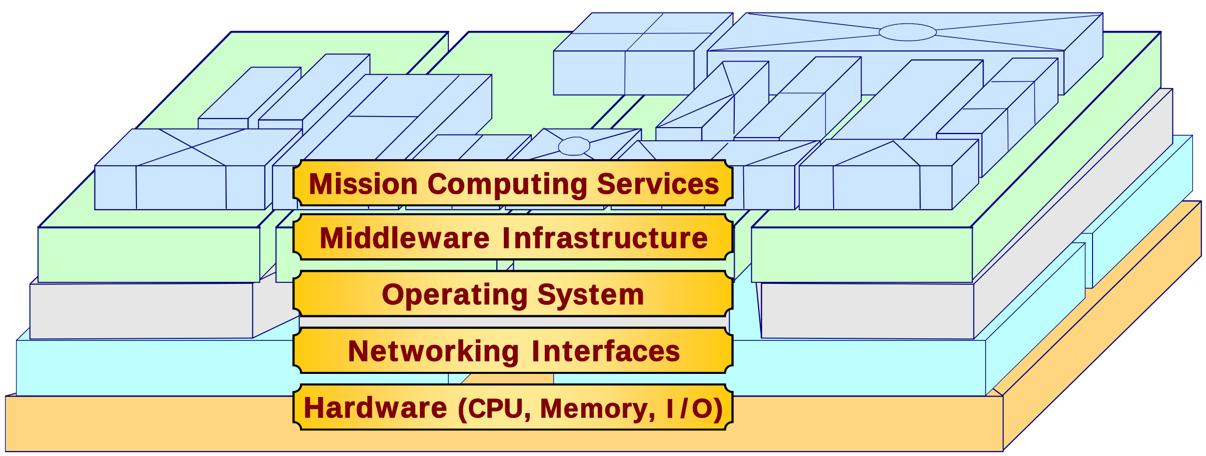
Product-line component model

- Configurable for product-specific functionality & execution environment
- Single component development policies
- Standard component packaging mechanisms
- 3,000+ software components

Benefits of Component Middleware

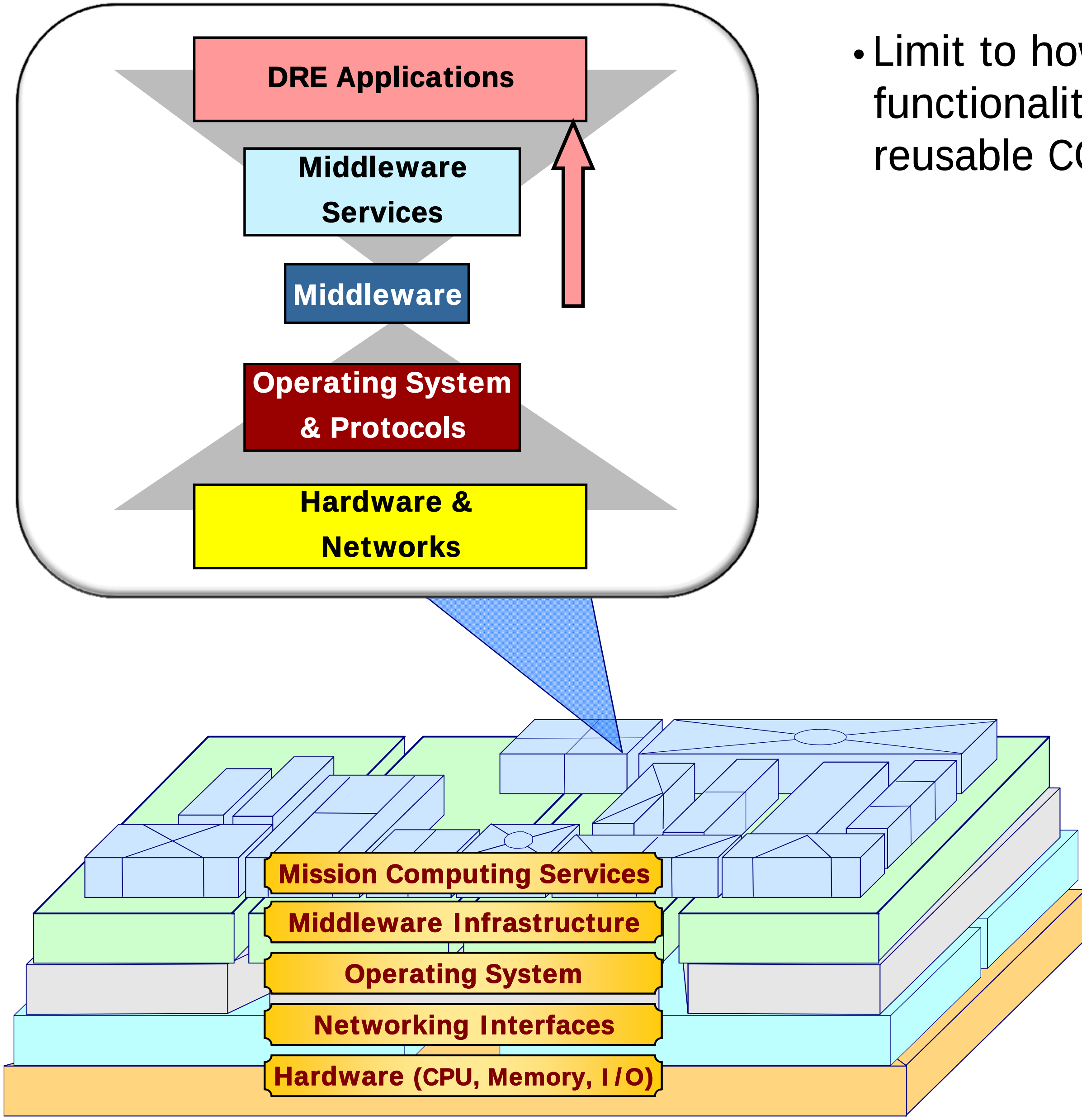
- Creates a standard “virtual boundary” around application component implementations that interact only via well-defined interfaces
- Define standard container mechanisms needed to execute components in generic component servers
- Specify the infrastructure needed to configure & deploy components thruout a distributed system





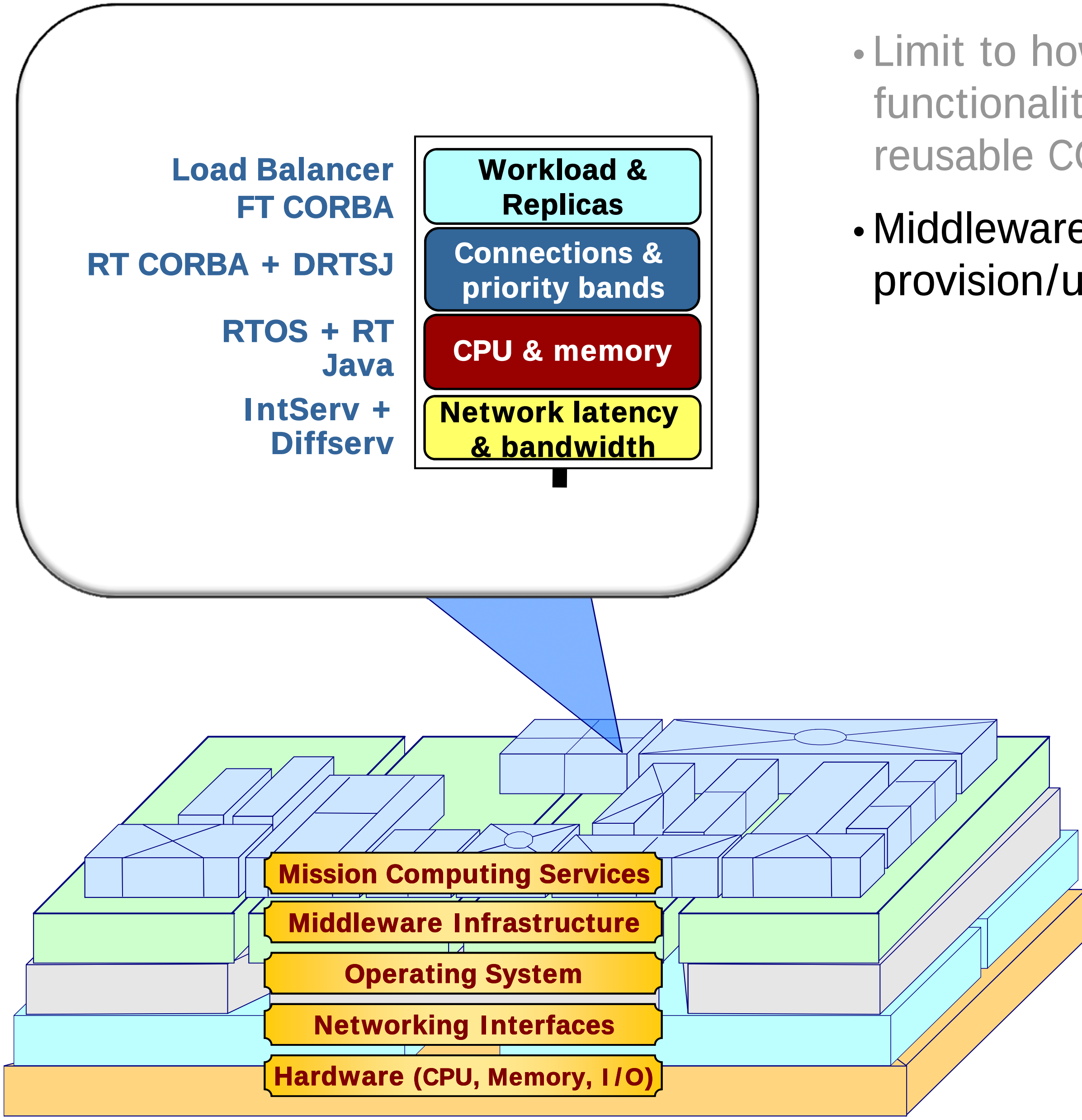

```xml
<ComponentAssemblyDescription id="a_HUDDisSPLy"> ...
 <connection>
   <name>GPS-RateGen</name>
<internalEndPoint><portName>Refresh</portName><instance>a_GPS<
/instance>
   </internalEndPoint>
   <internalEndPoint>
     <portName>Pulse</portName><instance>a_RateGen</instance>
   </internalEndPoint>
  </connection>
  <connection>
    <name>NavDisSPLy-GPS</name>
<internalEndPoint><portName>Refresh</portName><instance>a_NavDi
sSPLy</instance>
    </internalEndPoint>
<internalEndPoint><portName>Ready</portName><instance>a_GPS</i
nstance>
    </internalEndPoint>
  </connection> ...
</ComponentAssemblyDescription>
```

Limitations of Component Middleware



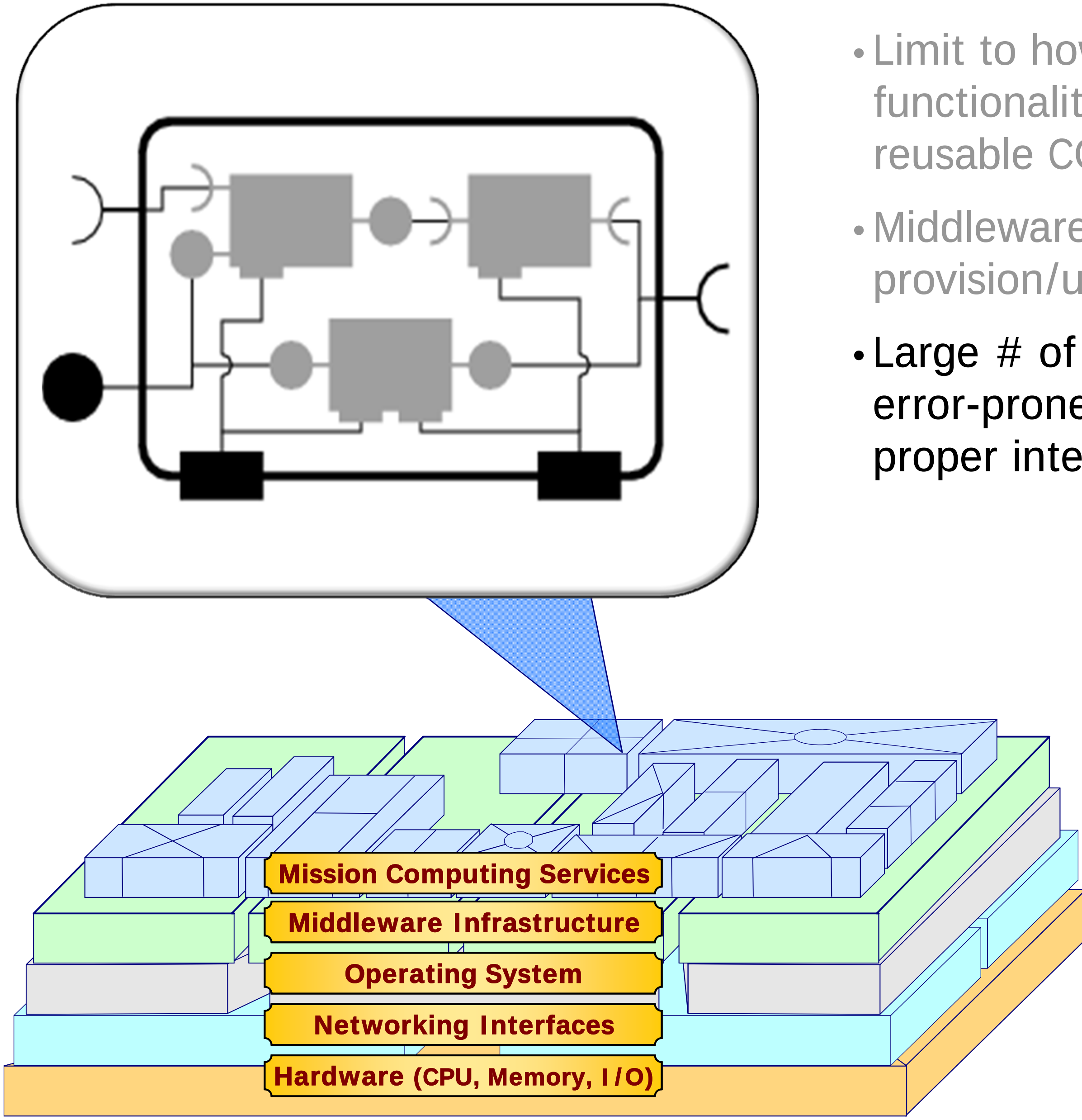
- Limit to how much application functionality can be refactored into reusable COTS component middleware

Limitations of Component Middleware



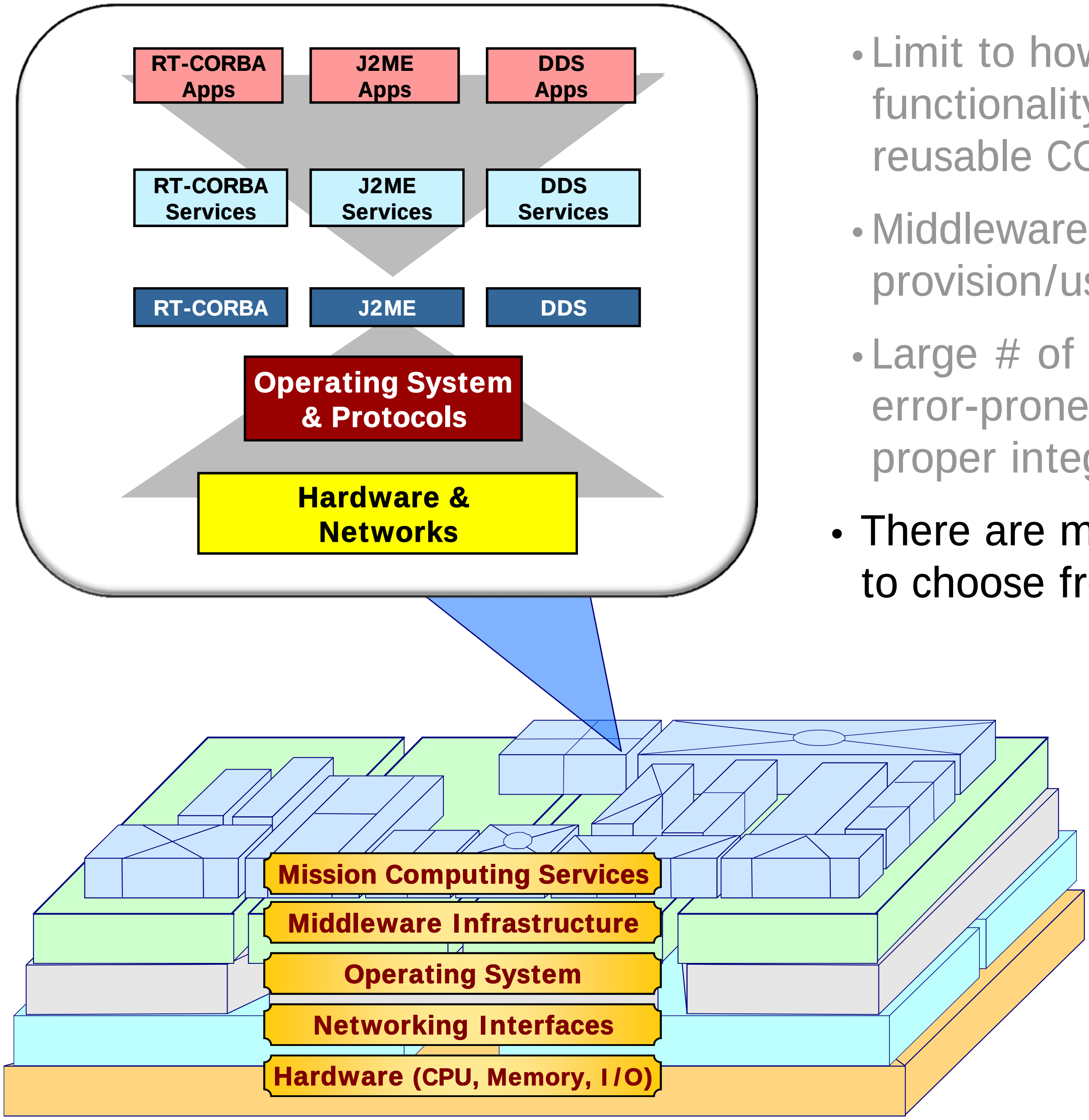
- Limit to how much application functionality can be refactored into reusable COTS component middleware
- Middleware itself has become hard to provision/use

Limitations of Component Middleware



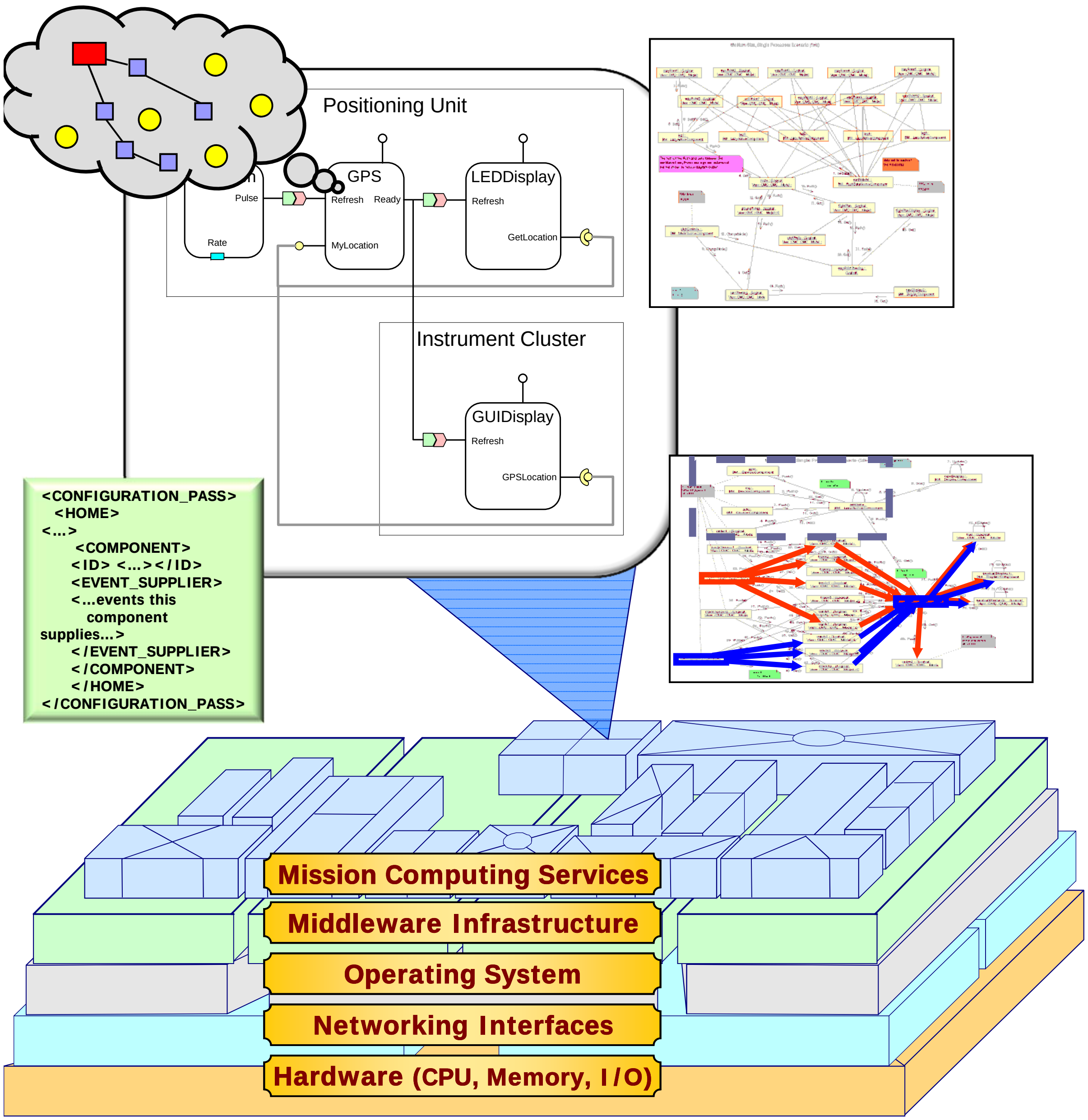
- Limit to how much application functionality can be refactored into reusable COTS component middleware
- Middleware itself has become hard to provision/use
- Large # of components can be tedious & error-prone to configure & deploy without proper integration tool support

Limitations of Component Middleware



- Limit to how much application functionality can be refactored into reusable COTS component middleware
- Middleware itself has become hard to provision/use
- Large # of components can be tedious & error-prone to configure & deploy without proper integration tool support
- There are many middleware technologies to choose from

Applying MDE to Bold Stroke



Model-driven engineering (MDE)

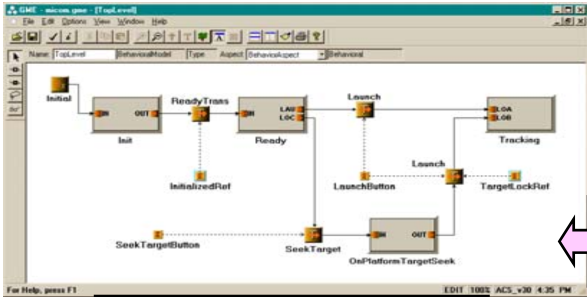
- Apply MDE tools to
  - Model
  - Analyze
  - Synthesize
  - Provision

  middleware & application components
- Configure product variant-specific component assembly & deployment environments
- Model-based component integration policies

www.isis.vanderbilt.edu/projects/mobies

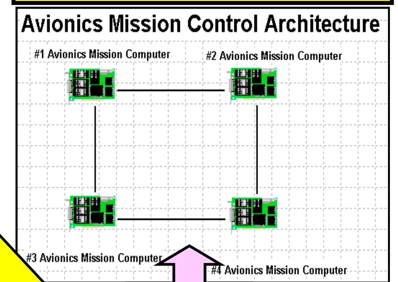
Applying MDE to Bold Stroke

UML/Rose
ESML/GME
PICML/GME



APPLICATION MODELING TOOLS

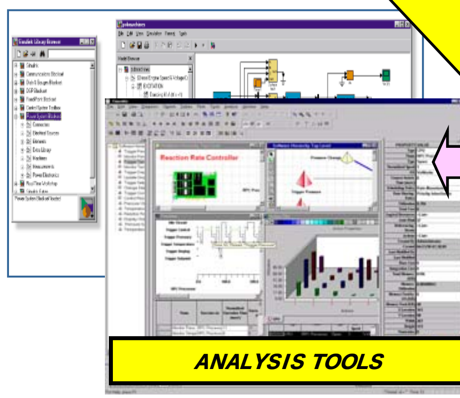
EMBEDDED PLATFORM MODEL



PowerPC
ACE+TAO
Bold Stroke

Formal mission specs, subsystem models, & computational constraints combined into integrated MDE tool chain & mapped to execution platforms

ARIES
TimeWeaver
TimeWiz
Cadena



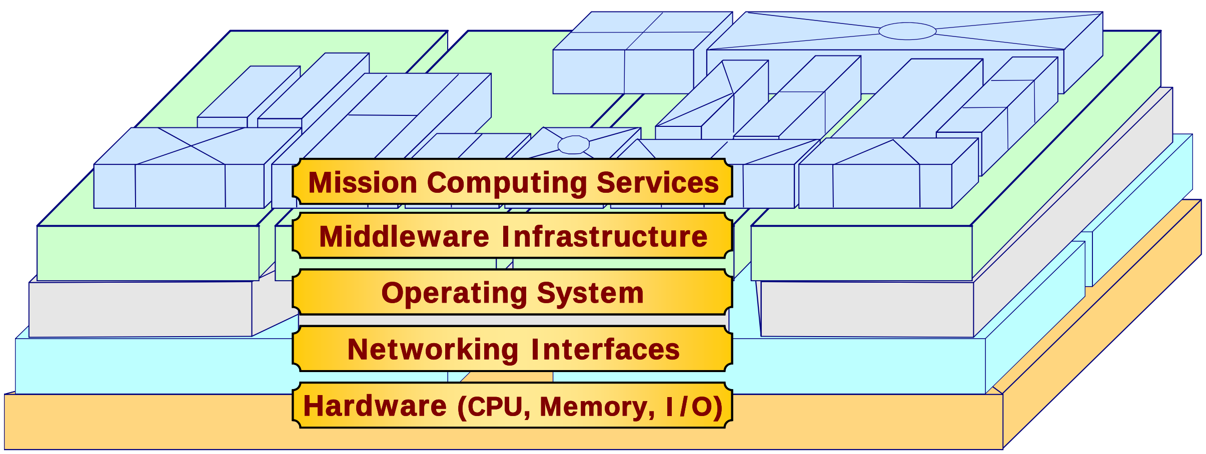
ANALYSIS TOOLS

Interaction is based on mission-specific ontologies & semantics

Stateflow
Statecharts
Ptolemy
Simulink
XML

C/C++
SMV
SPIN
Real-time Java
Ptolemy

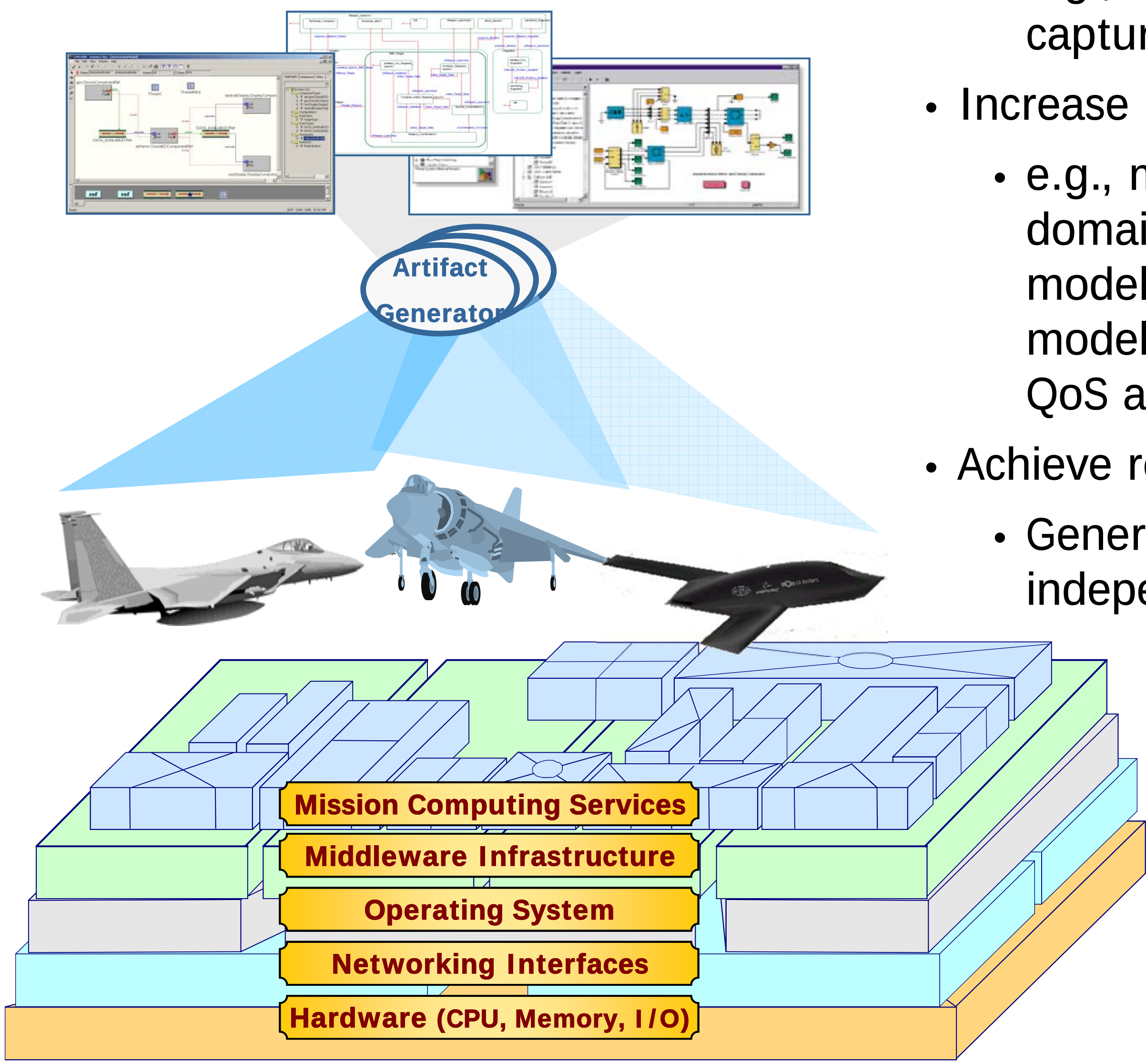
CODE GENERATORS



www.rl.af.mil/tech/programs/MoBIES/

Benefits of MDE

Avionics Mission Computing Modeling Languages



- Increase expressivity
  - e.g., linguistic support to better capture design intent
- Increase precision
  - e.g., mathematical tools for cross-domain modeling, synchronizing models, change propagation across models, modeling security & other QoS aspects
- Achieve reuse of domain semantics
  - Generate code that's more "platform-independent" (or not)!
    - Support DRE system development & evolution

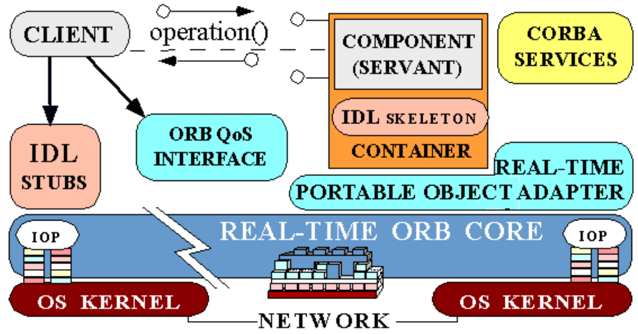
Limitations of MDE

- Modeling technologies are still maturing & evolving
  - i.e., non-standard tools
- Magic (& magicians) are still necessary for success

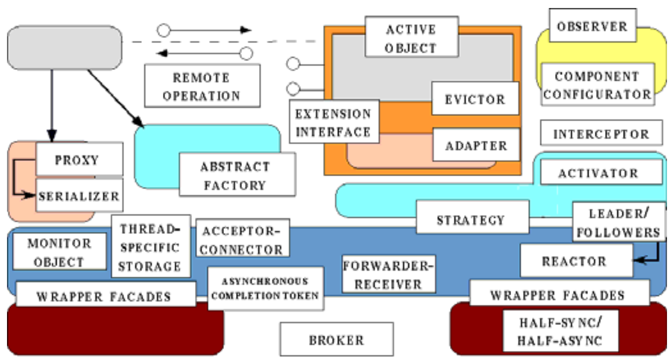
Ingredients for Success with Systematic Reuse

Key Technologies

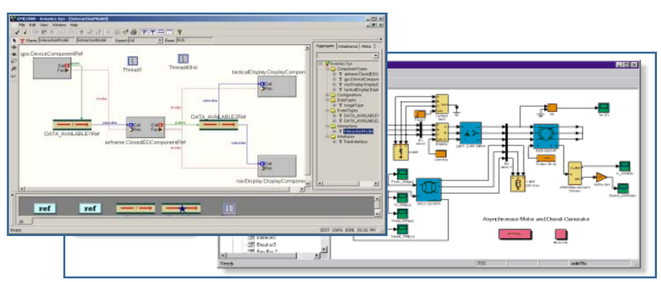
Standard Middleware, Frameworks, & Components



Patterns & Pattern Languages



Model-driven Software Development



Experienced Senior Architects

- Responsible for communicating completeness, correctness, & consistency of all parts of the software architecture to the stakeholders

Solid Key Developers

- Design responsibility (maintenance, evolution) for a specific architectural topic

Enlightened Managers

- Must be willing to defend the sacrifice of some short-term investment for long-term payoff

Accepted Business Drivers

- i.e., need a “succeed or die” mentality

It’s crucial to have an effective process for growing architects & key developers

Traits of Dysfunctional Software Organizations

Process Traits

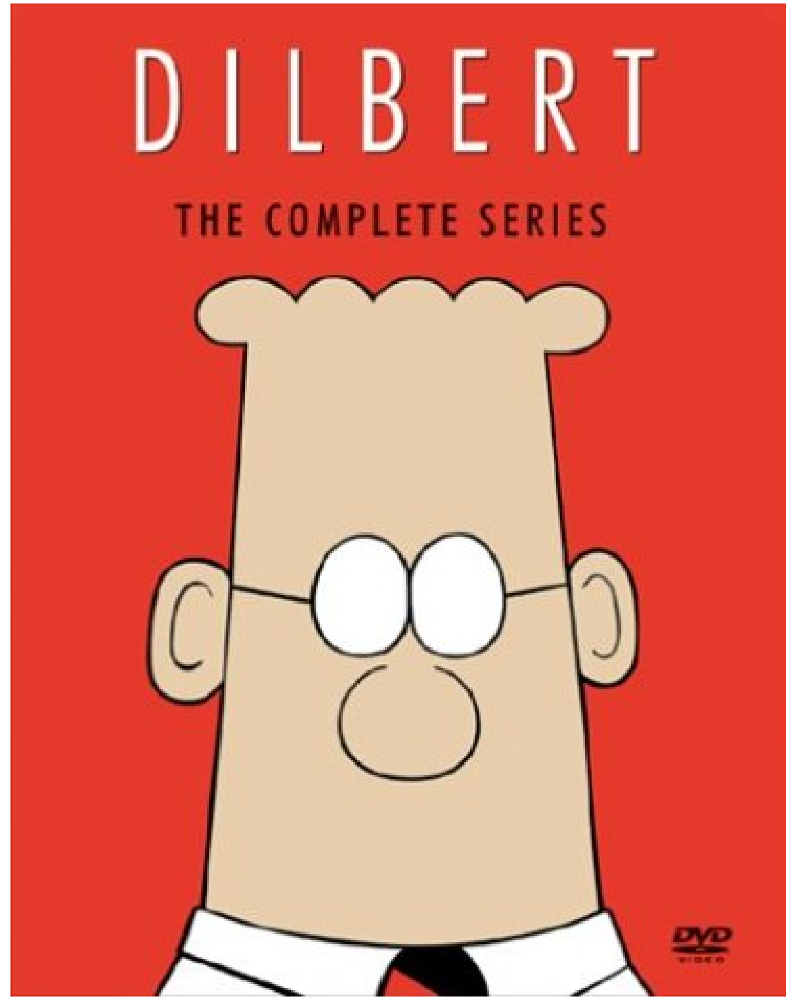
- Death through quality
  - “Process bureaucracy”
- Analysis paralysis
  - “Zero-lines of code seduction”
- Infrastructure churn
  - e. g., programming to low-level APIs

Organizational Traits

- Disrespect for quality developers
  - “Coders vs. developers”
- Top-heavy bureaucracy

Sociological Traits

- The “Not Invented Here” syndrome
- Modern method madness



www.dre.vanderbilt.edu/~schmidt/editorials.html

Traits of Highly Successful Software Organizations

Strong leadership in business & technology

- e.g., understand the role of software technology
- Don't wait for "silver bullets"

Clear architectural vision

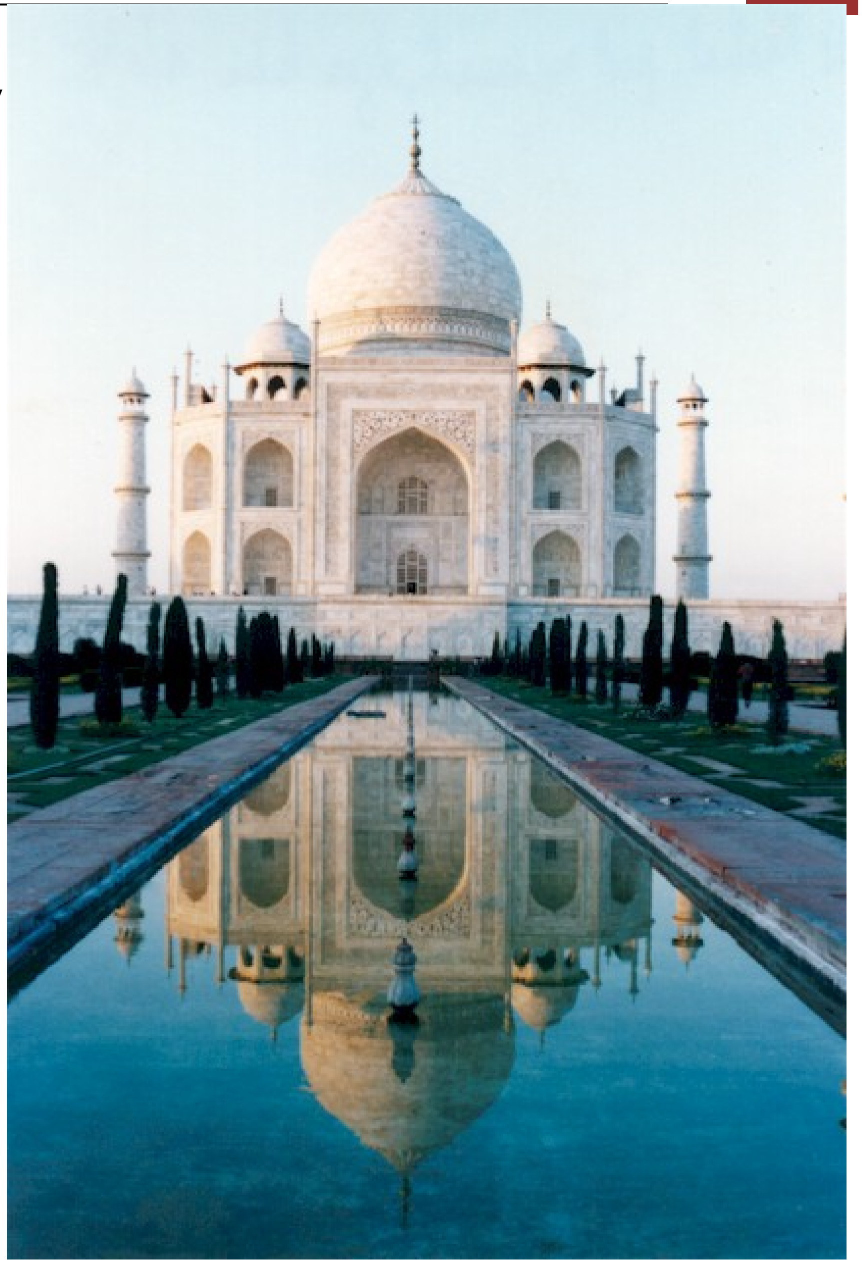
- e.g., know when to buy vs. build
- Avoid worship of specific tools & technologies

Effective use of prototypes & demos

- e.g., reduce risk & get user feedback

Commitment to/from skilled developers

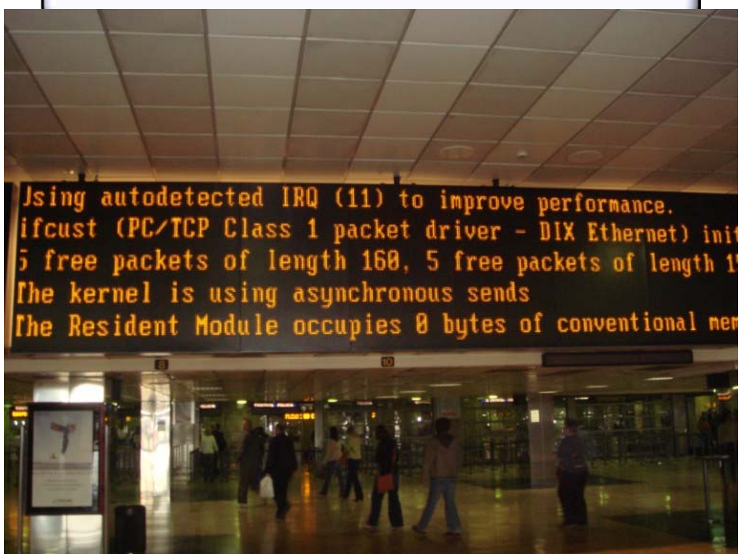
- e.g., know how to motivate software developers & recognize the value of thoughtware



Consequences of COTS & IT Commoditization

Applications

Domain-Specific Services



& Protocols

Hardware

- More emphasis on integration rather than programming
- Increased technology convergence & standardization
- Mass market economies of scale for technology & personnel
- More disruptive technologies & global competition
- Lower priced—but often lower quality—hardware & software components
- The decline of internally funded R&D
- Potential for complexity cap in next-generation complex systems

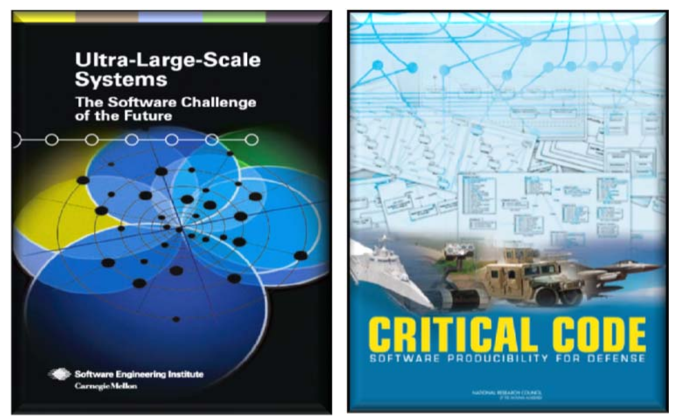
Not all trends bode well for long-term competitiveness of traditional leaders

Ultimately, competitiveness depends on success of long-term R&D on *complex* distributed real-time & embedded (DRE) systems

Concluding Remarks

- The growing size & complexity of DRE systems requires significant innovations & advances in processes, methods, platforms, & tools
- Not all technologies provide precision of legacy real-time & embedded systems
- Advances in Model-Driven Engineering & component/SOA-based DRE system middleware are needed to address future challenges
- Significant groundwork laid in DARPA & NSF programs

- Much more R&D needed to assure key quality attributes of DRE systems

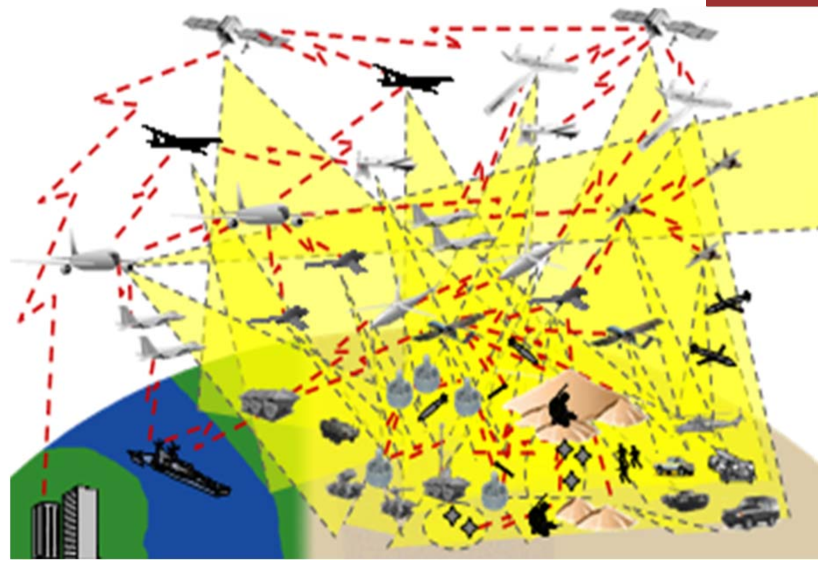


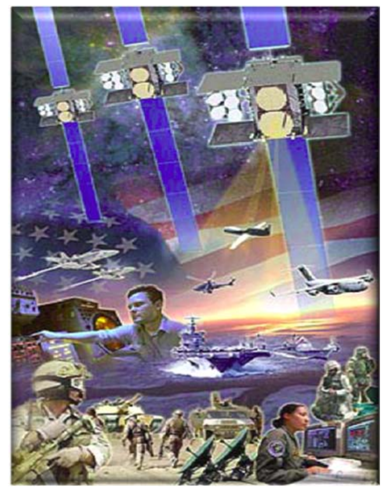
See blog.sei.cmu.edu for coverage of SEI R&D activities

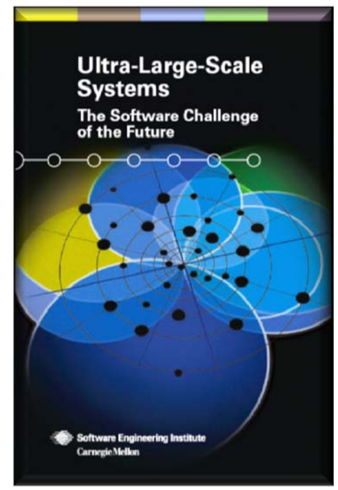
Further Reading

ULS systems are socio-technical ecosystems comprised of software-reliant systems, people, policies, cultures, & economics that have unprecedented scale in the following dimensions:

- # of lines of software code & hardware elements
- # of connections & interdependencies
- # of computational elements
- # of purposes & user perception of purposes
- # of routine processes & "emergent behaviors"
- # of (overlapping) policy domains & enforceable mechanisms
- # of people involved in some way
- Amount of data stored, accessed, & manipulated
- ... etc ...







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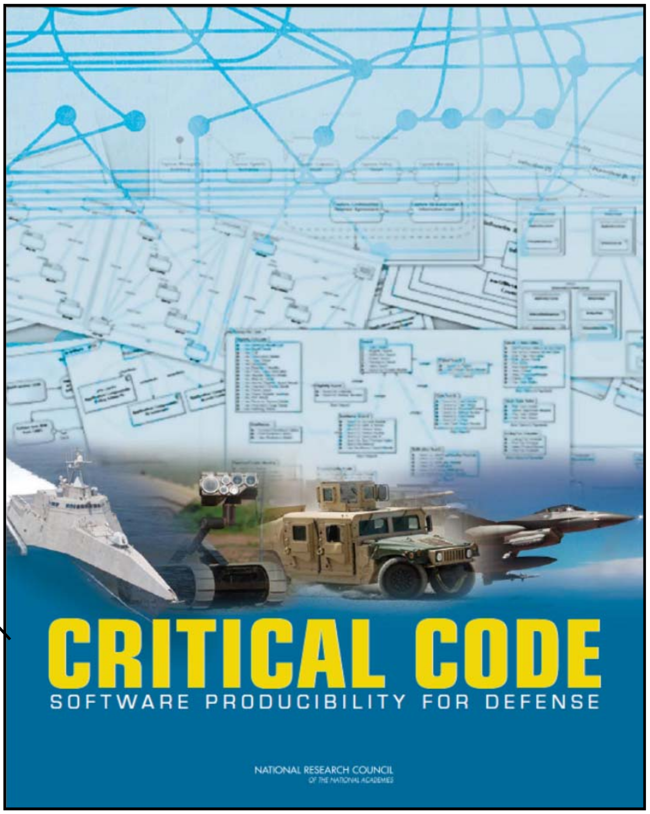
See blog.sei.cmu.edu for discussions of software R&D activities

Further Reading

NRC Report *Critical Code: Software Producibility for Defense* (2010)

Focus of the report is on ensuring the DoD has the technical capacity & workforce to design, produce, assure, & evolve innovative software-reliant systems in a predictable manner, while effectively managing risk, cost, schedule, & complexity



Sponsored by Office of the Secretary of Defense (OSD) with assistance from the National Science Foundation (NSF), & Office of Naval Research (ONR), www.nap.edu/openbook.php?record_id=12979&page=R1

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